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MANNED ORBITAL TRANSFER VEHICLE (MOTV)

volume 5
turnaround analysis

GRUMMAN AEROSPACE CORPORATION

MANNED ORBITAL TRANSFER VEHICLE (MOTV)

volume 5
turnaround analysis

prepared for
National Aeronautics and Space Administration
Johnson Space Center
Houston, Texas

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FOREWORD

This final report documents the results of a study performed under NASA Contract NAS 9-15779. The study was conducted under the technical direction of the Contracting Officer's Representative (COR), Herbert G. Patterson, Systems Design, Johnson Space Center. Mr. Lester K. Fero, NASA Headquarters, Office of Space Transportation Systems, Advanced Concepts, was the cognizant representative of that agency.

The Grumman Aerospace Corporation's study manager was Charles J. Goodwin. The major contributors and principal investigators were Ron E. Boyland, Stanley W. Sherman and Henry W. Morfin.

This final report consists of the following volumes:

- Executive Summary - Volume 1
- Mission Handbook - Volume 2
- Program Requirements Document - Volume 3
- Supporting Analysis - Volume 4
- Turnaround Analysis - Volume 5
- Five Year Program Plan - Volume 6

1 - ABSTRACT

Development of a routine turnaround process is required in order to employ the MOTV to enhance man's utilization of the geosynchronous space region. Since turnaround operations represent approximately 70% of the total MOTV mission, the process necessary to check, restore, and prepare the returning MOTV for its next mission should be analyzed and optimized to provide a reliable, low cost turnaround program.

A definition of the turnaround requirements for the S-1 MOTV configuration and an analysis of the primary sensitivity issues indicate the following.

The MOTV is a fairly sophisticated spacecraft with man-rated systems, including two RL10 II B engines, an attitude control and stabilization system, and a full complement of avionics and satellite servicing equipment. A routine cost effective turnaround plan must make maximum use of flight data for maintenance planning, a high degree of test automation and MOTV maintainability features in order to minimize tests, facilitate repair, and reduce the manpower requirements. Dollars spent on an effective turnaround maintenance program restore the returning MOTV hardware reliability to the design goals, providing a payback in terms of reduced risk.

The turnaround/maintenance analysis discussed in this report indicates the following:

- The recommended turnaround scenario starts out with ground turnaround because it utilizes in-place facilities, has the flexibility to deal with contingencies which will occur during the operational shakedown period, and provides a benign environment in which to gain experience, work out procedures, and refine support equipment requirements.
- SOC turnaround at 200 n mi provides a viable alternate because it decouples the turnaround operations from the STS support flights and saves approximately $11 M per mission. SOC turnaround, however, requires a significant investment in facilities, support equipment, and MOTV maintainability features, equaling approximately $330 M. Payback takes about 15 years, assuming an MOTV flight rate of six/year. The SOC option should be retained until the appropriate program milestone, when the following can be resolved:

- SOC operational altitude of around 200 n mi rather than the current assumption of 265 n mi

- Definitive costs of facility, MOTV design, and support equipment costs

- Portion of the initial investment for facilities which are chargeable to institutional improvements or other programs.

If the decision at the appropriate program milestone is to proceed with SOC, then the ground turnaround period of two to three years would be followed by an STS-tended LEO turnaround which would be used to qualify and refine the SOC equipment, procedures, and personnel. The final phase would utilize SOC on a progressive basis until the required operational capability was reached.

This report develops the support requirements for ground and LEO based turnaround. It discusses the maintenance analysis conducted and the sensitivity factors investigated, and substantiates the results summarized in the preceding paragraphs.

2 - STUDY OBJECTIVES

The basic purpose of this study was to define the support systems requirements for turnaround of the Manned Orbital Transfer Vehicle (MOTV) to accomplish the various manned geosynchronous mission scenarios. Specific objectives developed to accomplish the basic objective include:

1) Develop the MOTV turnaround scenarios
2) Define the turnaround functional requirements including maintenance, handling, transportation, and integration requirements
3) Identify the resources required in terms of manpower, GSE, facilities, and spares
4) Determine turnaround sensitivity issues
5) Consider the use of the Space Operations Center (SOC) as a potential element for MOTV assembly and turnaround in Low Earth Orbit (LEO)
6) Perform trades of selected significant turnaround issues
7) Select a baseline turnaround scenario for the MOTV based on the results of trades and turnaround analysis
8) Define the resources, i.e., manpower, skills, and support equipment required for the baseline turnaround
9) Identify the spacecraft design, facility, and technology impact associated with the baseline turnaround.

3 - BACKGROUND

MOTV turnaround is defined as the process required to restore an MOTV returning from a GEO mission to a predetermined state of readiness required to start the next GEO mission. The typical S-1 mission scenario illustrated in Fig. 3-1 illustrates the major turnaround activities, which include:

- Rendezvous, capture, and return of the MOTV to the refurbishment facility by the Orbiter
- Maintenance, refurbishment, and launch of the MOTV modules at the turnaround facility
- Assembly, checkout, and final mission preps of the MOTV at LEO and transfer to GEO for the next mission.

As indicated in Fig. 3-1, turnaround activities account for a major portion of the mission, approximately 70%, representing a major life cycle cost element. Thus, turnaround activities command significant attention and analyses throughout the various program phases.

For the scenario illustrated in Fig. 3-1, LEO turnaround operations are limited to assembly, checkout, and final mission preps of the MOTV modules. The major portion of the turnaround time is spent on the ground, for the illustrated scenario. Figure 3-2 illustrates the major MOTV ground activity that is accomplished under the umbrella of the 160 hour (10 day) Shuttle turnaround shown in Fig. 3-1. MOTV maintenance, conducted in the Vertical Processing Facility, is the major task for the activities illustrated in Fig. 3-2.

3.1 MAINTENANCE & PAYBACK

The value of a maintenance program which can restore the returning MOTV to a readiness state consistent with the crew safety and mission success design criteria can be illustrated through the following example. It is reasonable to assume that an MOTV returning from a 19-day mission could have some failed components on board. Without any maintenance and refurbishment, this would result in a degraded mission success probability. Fig. 3-3 shows the S-1 costs per flight, and turnaround costs are \$125 x 10^6 and \$3.53 x 10^6. In the example selected, a degraded reliability of 0.8 is assumed

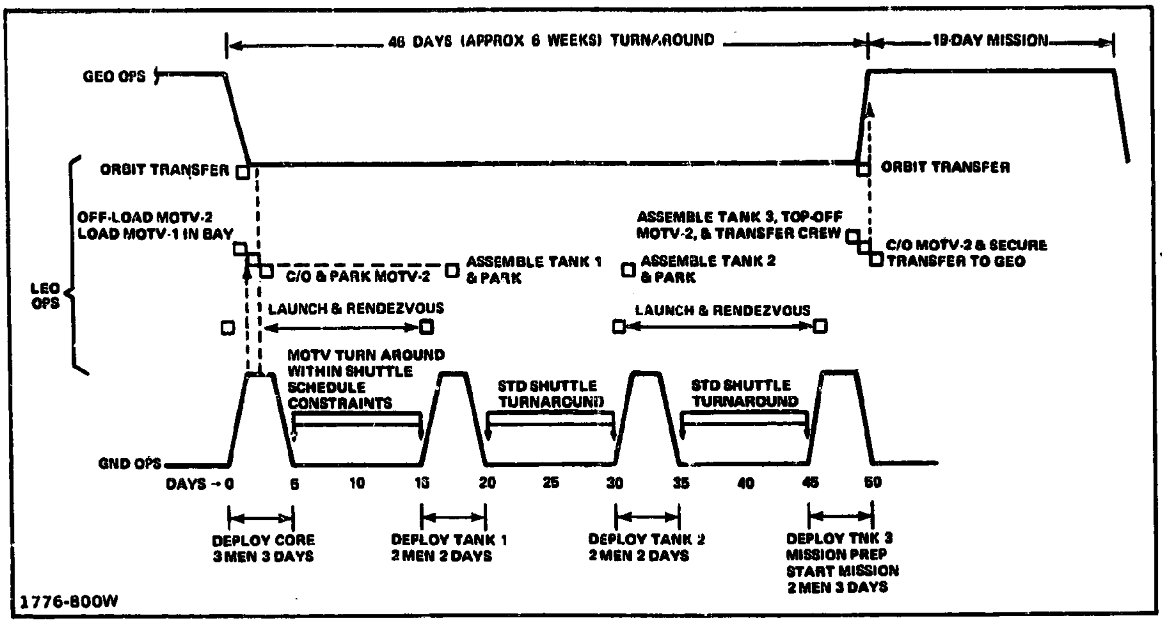

Fig. 3-1 MOTV Turnaround Scenario

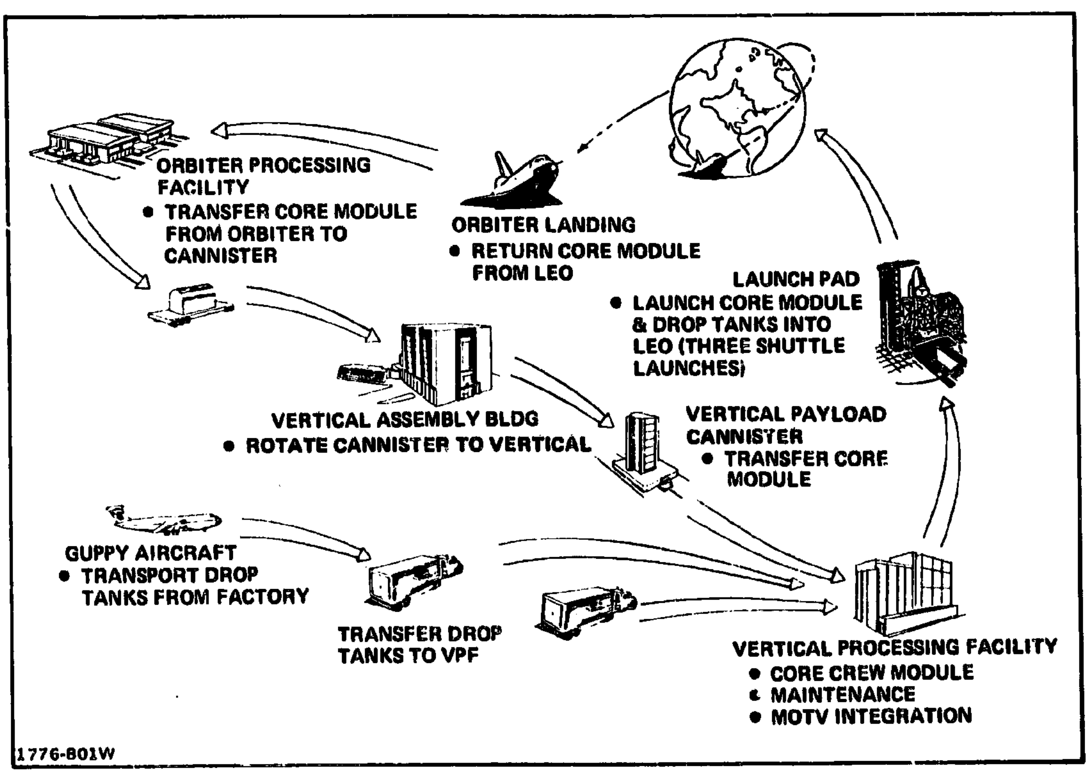

Fig. 3-2 Ground Turnaround Activity

	CREW CAPSULE	PROPULSION CORE	DROP TANKS (3)	TOTALS
MANAGEMENT				0.78
CREW PROVISIONS	0.30			0.30
TURNAROUND	2.25	1.28	–	3.53
FUEL		0.02	0.10	0.12
DROP TANKS			7.04	7.04
GROUND SUPPORT				3.62
MISSION OPS				0.34
SUB TOTAL				15.63
SPACE TRANSPORT	├──38.1──┤		71.27	109.37
TOTAL				125.00
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Fig. 3-3 Typical Cost per Mission – Service Mission S-1 (Constant 1979 $M)

as a result of failed components during a 19-day mission. Maintenance restores the refly mission reliability to the 0.97 design goal. Improving reliability from 0.8 to 0.97 reduces the possibility of abort by approximately an order of magnitude (20% to 3%). Assuming that 75% of the turnaround costs is for maintenance, the equivalent dollars risked can be reduced by 25M-3.75M/3.53 x 0.75 = $8 for every dollar spent on turnaround maintenance for the example illustrated in Fig. 3-4. Reducing the costs of an effective maintenance program will maximize the payback which further illustrates the need for continued program emphasis on maintenance and turnaround activities.

3.2 PRELIMINARY ANALYSIS RESULTS

Early in the overall Manned Geosynchronous Mission Requirements analysis study, a preliminary analysis indicated that a gain in MOTV performance of about 13% could be realized by using LEO instead of the ground as the operational turnaround base. A preliminary turnaround analysis on the possibility of LEO turnaround was conducted. Typical ground turnaround operations were defined, manloaded and, from this baseline, LEO candidate task manhours were adjusted to reflect EVA operations at LEO. Preliminary results discussed in References 1 and 2, and summarized in Figs. 3-5 and 3-6, indicated:

- Ground-based is the preferred MOTV turnaround mode for the early MOTV operational period, because it utilizes existing KSC facilities and is flexible (thereby capable of accommodating contingencies)
- Standard Shuttle-tended LEO turnaround is not practical because of the manpower and cargo limitations; LEO turnaround with a LEO depot should be investigated.

Further analysis of the preliminary activities, manpower, and task times developed to accommodate our preliminary turnaround strawman flow indicated that these data were sensitive to several maintenance issues, namely:

- Maintenance approach
- Checkout Autonomy
- Accessibility
- Turnaround location
- Horizontal vs vertical ground turnaround processing
- Structure and exterior surface materials.

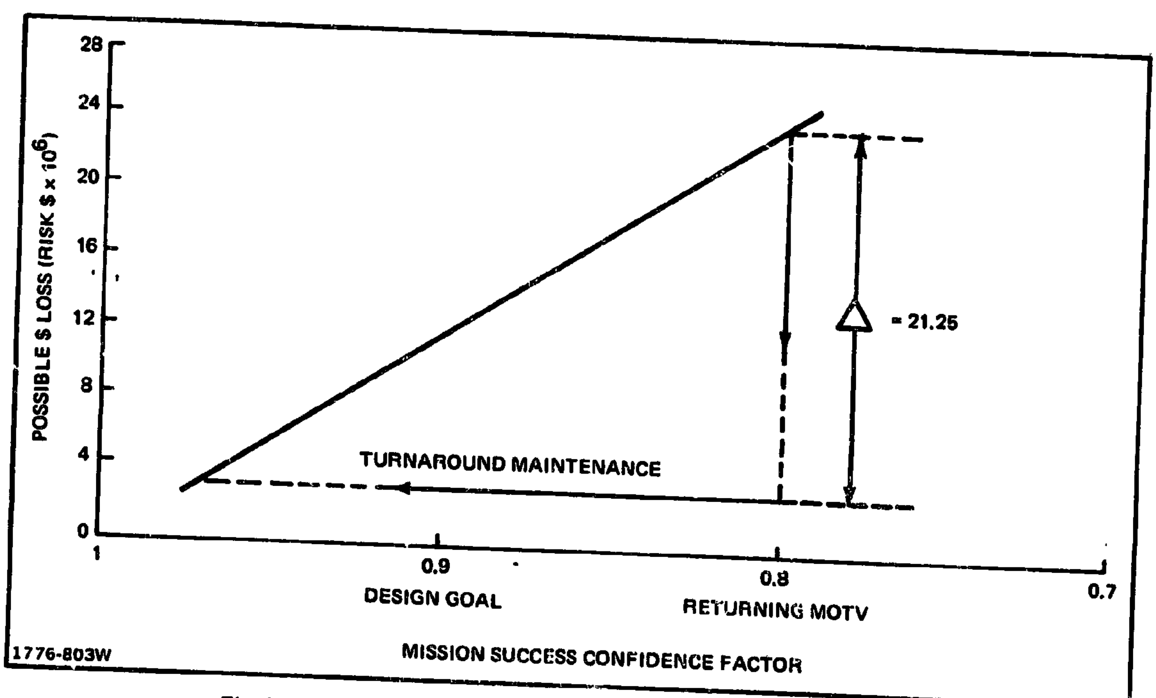

Fig. 3-4 Maintenance Payback – Reducing Risk Through Maintenance

TASK NO.	FUNCTIONAL REQM'T	GND MAN POWER ESTIMATE: MAN – MOD (MM) NO.	HR	M HR	CORE MOD (CM) NO.	HR	M HR	DROP TNK (DT) NO.	HR	M HR	LEO CANDIDATE TASKS: GROUND EQUIV M/HR	GROUND TOTAL M HR
3.1	POSITION XPORTER & ATTACH HANDLING SLINGS				5	1.5	7.5					
3.2	ROTATE CANNISTER				9	1	9					
3.3	ATTACH LIFTING SLING TO CORE/MAN MOD ASSY				4	0.5	2					
3.4	REMOVE CORE ASSY & INST IN INTEG WK STND				10	1	10	NOT				
3.5	INSTALL WK PLTFORMS				4.5	2.0	9				9	
3.6	POST FLT EXT INSPEC & PHOTOGRAPHY				8.0	4.0	32				32	
3.7	POSITION & MATE GSE				6.5	2	13				4	
3.8	ESTABLISH CABIN CONDIT & TNK PURGES	3	1	3	4.0	1	4				7	
3.9	REMOVE DOORS & HATCHES	2	1	2	2	1	2				4	
3.10	POST FLT DAMAGE INSP	5	6	30	2.0	6	12				42	
3.11	REMOVE CABIN EQUIP	4	2	8							8	
3.12	CLEAN CABIN & CORE EXTERIOR	2	8	16	2.0	8	16	APPLICABLE			32	
3.13	SCHEDULED MAINT											
3.13.1	CONTINUING INSPECTION & PHOTOGRAPHY OF AREAS, COMPONENTS & EQUIP. FOR WEAR DETERIORATION, DAMAGE, ETC. SEE TABLE A	6	10	60	2	10	20				80	
3.13.2	REMOVAL OF TIME LIMIT & EXPENDABLE ITEMS	5	10	50	2	10	20				70	
3.13.3	SYSTEM & FUNCTIONAL, SEE TABLE A	33	20	660	12	20	240	TANKS			900	
3.14	UNSCHED MAINT (TYPICAL)											
3.14.1	DISASSY OF SELECTED AREA	20	20	400	10	12	120				520	
3.14.2	FURTHER INSPECTION OF SELECTED AREAS	10	10	100	5	6	30				130	
3.14.3	DIAGNOSTIC TESTING	34	20	680	15	10	150				830	
3.14.4	REMOVE & REPLACE	17	20	340	9	10	90				430	
3.14.5	REVALIDATE	34	8	272	15	6	90				362	
3.14.6	INPLACE REPAIRS	15	24	360	8	12	96	LEFT			200	
TOTAL MAINT (SCHED & UNSCHED)				2981			972				3680	
4.0	EDT C/O CELL MAINT ACTIVITY COVERED IN 3.0											
5.0	MM C/O CELL MAINT ACTIVITY COVERED IN 3.0											
6.0	INTEGRATE MOTV CONFIG											
6.1	MATE EDT TO CM, CONN ALL INTER & INSPECT				8	4	32	AT			32	
6.2	MATE MM TO CM, CONN ALL INTER & INSPECT				9	4	36					
6.3	VERIFY ALL INTERFACES				11	2	22				22	
6.4	PERFORM MISSION READINESS TEST				20	8	160				160	
6.5	PWR DOWN & SECURE ALL SYSTEMS				4	3	12				12	
6.6	CLOSE OUT CABIN				6	8	48				48	
6.7	DISCON & REMOVE GSE				3	3	9				2	
6.8	INSTALL TNK SLINGS				2	1	2					
6.9	DEMATE EDT & INST IN CONT				5	2	10	GEO				
6.10	INSTALL CM SLINGS				2	0.5	1					
6.11	REMOVE KW FLAT FORMS				4	2	8				2	
6.12	REMOVE CM FR WK STAND & INSTAL IN CONT				5	2	10					
6.13	TRANSPORT TO PAD				2	4	8					
TOTAL FOR INTEGRATION							358				278	3938

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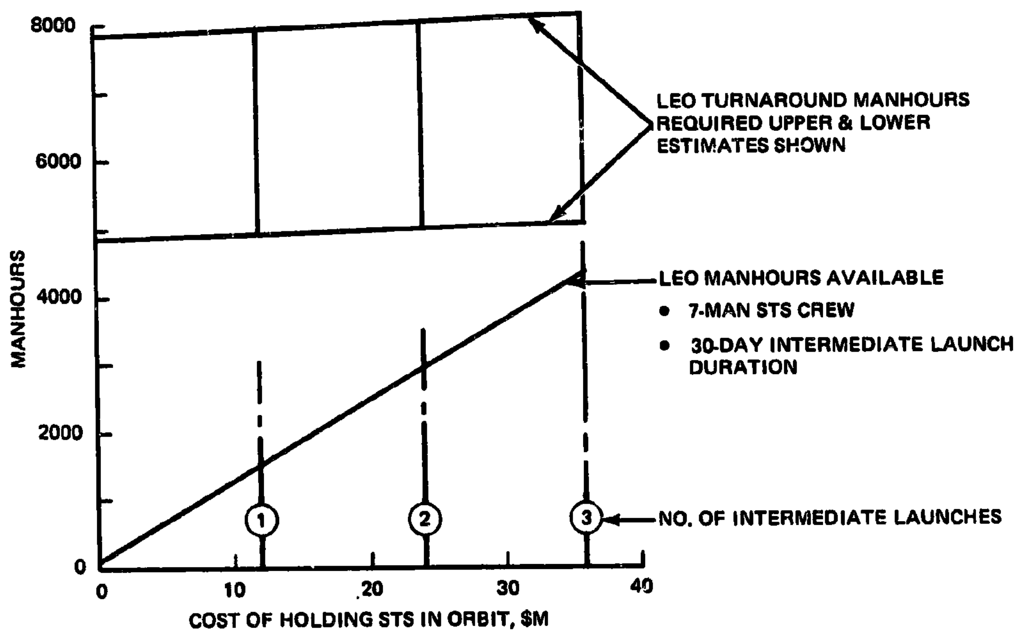
Fig. 3-5 MGMR Turnaround Analysis for 1 ½ Stage MOTV at Vert Processing Facility

- PERFORMANCE (PAYLOAD) WITH LEO TURNAROUND IS HIGHER THAN GROUND TURNAROUND
- LEO TURNAROUND FEASIBILITY: PRORATED VALUE = $12/16M



- CONCLUSIONS
  - SHUTTLE CREW ACCOMMODATION TO SMALL AS WORKING BASE FOR MOTV LEO TURNAROUND
  - AT HIGH TRAFFIC VOLUME, LEO DEPOT COULD BE COST-EFFECTIVE

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Fig. 3-6 LEO Turnaround – STS-Tended

All of these issues are interdependent, but the first three are extremely interactive and, as a set, serve to establish a basis for evaluation of the others. The fourth, location, is probably the biggest cost driver, having overall program implications as well as an impact on the direct turnaround costs. The last three were considered secondary issues. We therefore elected to treat the first three issues as a set and use the resultant data to evaluate the effect of changing the turnaround base of operations from the ground to LEO. These trades were included in the overall MOTV turnaround analysis discussed in the following sections.

4 - STUDY APPROACH/METHODOLOGY

Our study approach was to conduct a comprehensive MOTV turnaround analysis which would establish a viable approach and the support requirements for KSC ground-based and LEO Space Operations Center (SOC)-based turnaround operations. The methodology used is illustrated in Fig. 4-1, and consisted of:

a) Reviewing commercial airlines and military aircraft data and, if relevant, utilizing it to formulate our approach to MOTV turnaround.

b) Utilizing the results of (a) together with our knowledge of the MOTV mission and configuration to define our turnaround philosophy, the ground rules and assumptions and a baseline MOTV subsystem configuration for the analysis.

c) Defining basic subsystem maintenance and overall turnaround around analysis.

d) Developing scenarios, functional tasks and timelines consistent with the above.

e) Defining support requirements for the ground and LEO based turnaround options.

f) Analyzing the turnaround options.

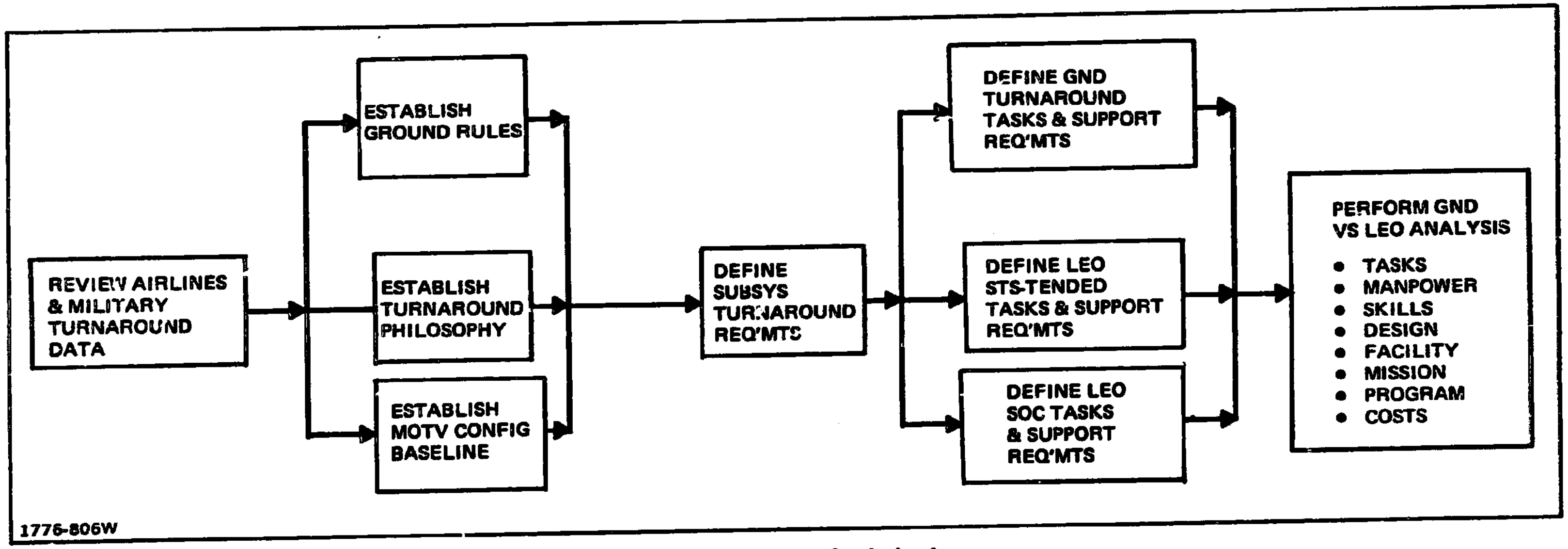


Fig. 4-1 Turnaround Study Logic

5 - TURNAROUND REQUIREMENTS DEFINITION

Turnaround requirements are influenced to a large degree by the maintenance philosophy and groundrules established.

5.1 MAINTENANCE PHILOSOPHY

Our review of military and airlines data indicates that airlines experience is relevant to our situation because of the importance it places on cost. Airline management has devoted considerable attention to turnaround maintenance of their wide-body jets. They have collected a significant body of data on maintenance approach, reliability, and fleet experience and have drawn conclusions which, though not directly transferable, nevertheless relate to MOTV turnaround. Figure 5-1 illustrates the basic maintenance philosophies which have evolved in the industry and which are defined in the following paragraphs.

5.1.1 Time Limit

Maintenance requiring routine inspection, replacement, and/or overhaul of a component, assembly, or subsystem on the basis of duty hours, cycles, flights, or calendar time is time-limited. Extensive analyses of aircraft components indicate this philosophy is an effective way of preventing failures in simple "single celled" parts or specific modes of complex hardware, all of which exhibit a fairly predictable deteriorating failure rate with age. Landing gear components, thermal protection tiles, brakes, and engine components are examples of time limit candidates.

This philosophy is not effective for complex assemblies where maintenance activity can induce failures due to people, procedures, or random failure of replacement parts. Overall, the "time limit" philosophy is labor and parts intensive, and is therefore costly.

5.1.2 On-Condition

Maintenance action based on the actual condition of the component, complex assembly, or subsystem has been studied. This is effective, providing the hardware has a measurable physical standard which is highly correlated to its operation, and the physical standard provides an early warning signal. This concept is cost effective because maintenance action is taken only when required. The cost of the instrumentation and

PHILOSOPHY	PRE REQUISITE	MAINTENANCE TASK	CHARACTERISTIC
TIME LIMIT	RELIABILITY DECREASES WITH AGE	REPLACE PRIOR TO FAILURE (TIME)	EXPENSIVE & SAFE
ON CONDITION	MEASURABLE PHYSICAL STANDARDS	MONITOR – REPLACE BASED ON CONDITION	LOW COST & SAFE
AFTER FAILURE	NONCRITICAL COMPONENTS	ASSESS CAUSE	LOWEST COST BUT RISKY

1776-807W

Fig. 5-1 Maintenance Program Options

data processing required is one of the prime cost drivers for this concept. Brake replacement based on physical deterioration of the pads and avionic or fluid systems with built in test points are examples of "on-condition" maintenance items.

5.1.3 After Failure

Unlike the two previous concepts, this philosophy is not preventive. It allows a malfunction to occur and then relies on an analysis of the information relating to the malfunction to determine whether additional corrective action should be taken. It is a supplement to "time limit" and "on-condition" maintenance, utilizing the data from unscheduled removals, confirmed failures, pilot reports, inspections, repair shop reports, and reliability reports to "flag" the need for additional corrective action.

The MOTV maintenance program would encompass all three concepts, with the emphasis on "on-condition" maintenance. Operational Flight Instrumentation (OFI) would be used extensively to continuously monitor the condition of all subsystems during the mission. Recorded results are processed by ground computers, compared against previous results, with the trend data for the particular component or subsystem used as the basis for judging maintenance requirements. Anomaly reports would be used to monitor the overall effectiveness of the maintenance program and make adjustments in the maintenance procedures or recommend design changes.

5.1.4 MOTV Philosophy

For the MOTV, condition monitoring is our basic philosophy, with time limit replacement used only for those items like engine components which wear out with time because of the high stress imposed by performance requirements. Figure 5-2 illustrates our concept for implementing the philosophy. It illustrates the methods for determining the condition of the returning MOTV, the maintainability design features required, and the techniques involved.

The MOTV maintenance scenario summarized in Fig. 5-2 includes:

- Real time and post flight analysis of flight data
- Post flight internal and external inspections to determine the condition of structural, mechanical propulsion, and electrical equipment
- Post maintenance leak checks to determine system, seal, lines, and tank integrity
- Post maintenance functional tests of equipment condition.

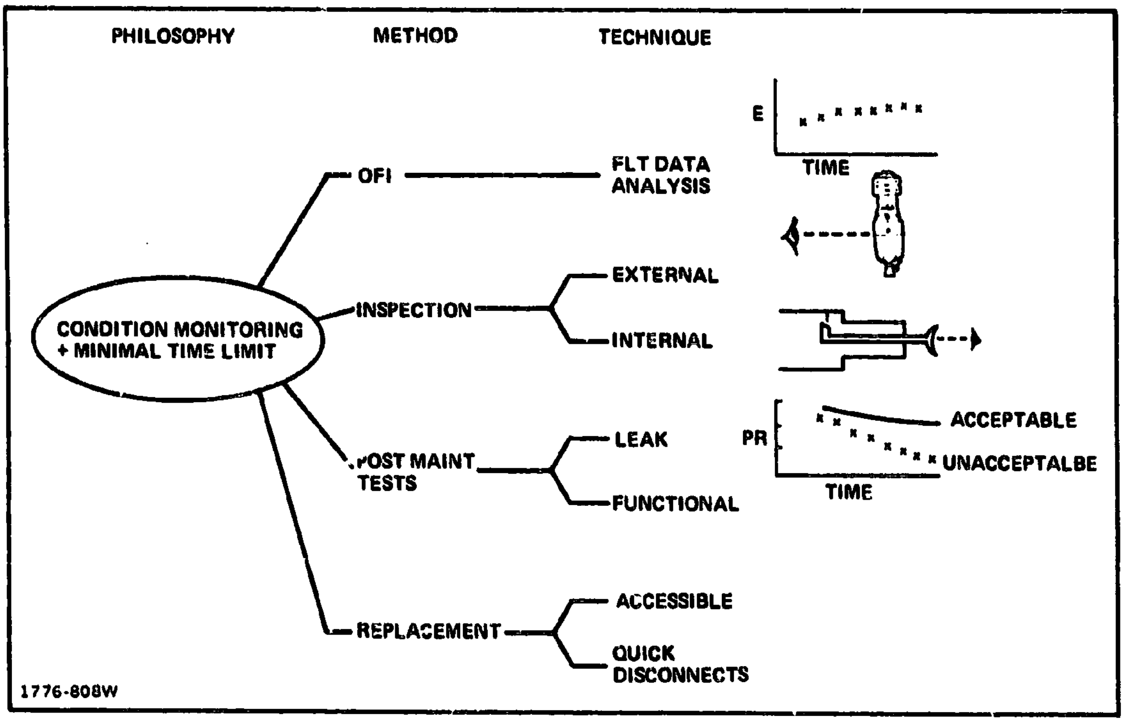


Fig. 5-2 Ground Turnaround Approach Summary

Figure 5-3 illustrates and indicates the prime differences between the approach used to develop the initial turnaround data discussed in paragraph 3.2 and the update baseline.

5.2 CONFIGURATION

The "all propulsion" MOTV configuration for support of the inspection, service, and repair missions, S-1, was selected as the baseline for the turnaround analysis. Figure 5-4 shows the overall configuration and general characteristics. It has a common core for all missions with a 20,000 KG propellant capacity contained in the aft liquid oxygen tank and the hydrogen tank. Thrust is provided by two RL10 Cat IIB engines. The vehicle is controlled by RCS thrusters mounted in four modules located about the c.g. providing translation along the three axes and pitch, yaw, and roll control. The crew is housed in the forward crew capsule having a 25 m^3 volume. The electrical power system is mounted on the core with fuel cells located between the tanks. Radiators to thermally control the fuel cells are mounted on the inter-tank skirt and the solar cell array mounted on the propulsion core thrust structure. Distribution of the other subsystems is indicated in Fig. 5-5.

The degree of definition for the S-1 MOTV configuration was expanded to the level required for the maintainability analysis. This included synthesizing functional schematics for the various subsystems and assuming maintainability features. The subsystem schematics and descriptions are included along with the maintenance requirements in paragraph 5.3.

The key maintenance concern is condition assessment. The most effective method for determining the health and failure resistance of the equipment is by analyzing the flight data, because it provides:

- Equipment performance data in the operational environment and with a wide spectrum of inputs and/or functional variations
- RF link provides in-flight maintenance analysis and therefore positive slack for assembly of required resources for post-flight maintenance
- In-flight analysis also improves support Shuttle cargo loading efficiency
- Flight data reduces ground tests and therefore minimizes turnaround manpower, test equipment, and schedule test time.

The MOTV should therefore feature extensive OFI with significant number of built-in test points and test equipment, recording, and RF transmission equipment.

	PRELIM BASELINE	UPDATED BASELINE
PHILOSOPHY	NONE	CONDITION MONITORING + MINIMAL TIME LIMIT
AUTOMATION	AUTOMATED GND EQUIP + STD OF I, GND DATA PRIME MAINT. ANALYSIS TOOL	AUTOMATED GND EQUIP + MAXIMUM OF I, FLT DATA PRIME MAINT ANALYSIS TOOL
ACCESSIBILITY	STD	MAXIMUM EXTERNAL & INTERNAL (BORESCOPE TYPE)
MANAGEMENT	TEAM SUBSYSTEM SPECIALISTS ON LINE	TEAM SYSTEM ENGINEERS ON LINE

1776-809W

Fig. 5-3 Ground Turnaround Update vs Preliminary Baseline

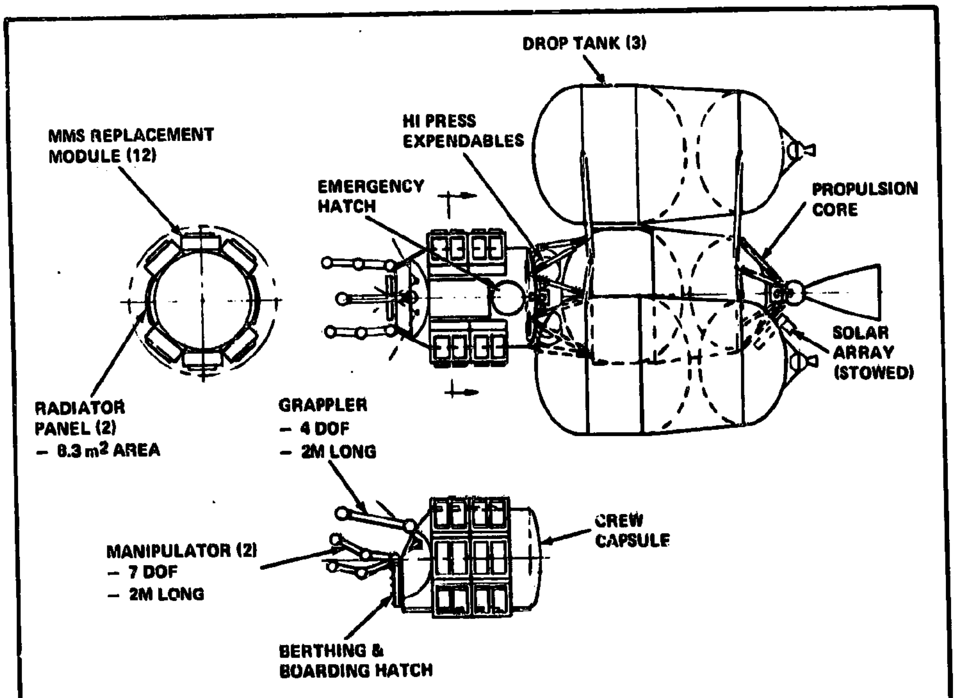
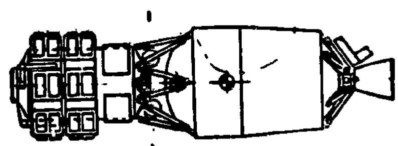


Fig. 5-4 MOTV GEO Transfer Config for Mission S-1



AVIONICS: SUBSYSTEM	CREW CAPSULE	PROPULSION MODULE	DROP TANKS
• DISPLAYS & CONTROLS	ALL		
• DATA MANAGEMENT	TAPE RECORDER, (30%) SIGNAL CONDITIONERS BIO-MED + ECLSS SENSOR	60%	TEMP, PRESSURE (10%) SENSORS
• ATTITUDE CONTROL & DETERMINATION	MANUAL NAVIGATIONAL(30%) CONTROLS, KEYBOARD COMPUTER INPUT, DIGITAL INTERFACE UNIT	70%	
• TRACKING, TELEMETRY & COMMAND	CREW MICS., EARPHONES,(15%) ENCRYPTORS, DECRYPTORS	85%	
• RENDEZVOUS RADAR	ALL		
• EPS	CONTROLS & CKT (20%) PROTECTION	80%	

LOCATION CRITERIA
- MAINTAINABILITY
- RELIABILITY
- WEIGHT/CG
- UNNAMED FLIGHT
- ON-ORBIT REPAIR
- DETERMINED BY USE

1776-811W

Fig. 5-5 Initial Subsystem Location

OFI must also provide an LPS interface and LPS compatible software for processing in-flight and ground test data. In addition, the MOTV must provide accessibility to the subsystem components, and for inspection of fluid systems.

5.3 SUBSYSTEM MAINTENANCE & TURNAROUND REQUIREMENTS

The MOTV S-1 configuration was analyzed to derive the requirements for each of the subsystems which are discussed in the following paragraphs.

5.3.1 Structural Mechanical Requirements

The basic MOTV structure, Fig. 5-4, consists of the core module, drop tank, and manned module structures. The core module aluminum outer shell or skirt is an integral part of the LH_2 core tank. The LO_2 tank is independent and is attached to the ski with struts. Thrust loads from the two RL10 main engines are transferred to the skirt through a series of struts. Engine gimbal mechanism maintenance requirements are covered under propulsion. The drop tanks are attached to the core through a series of struts with solenoid-operated latches for separation on command. The manned module is attached to the core with a series of struts and accessible standard bolts for ground mate or demate operations.

The drop tank structure is similar to the core, with the skirt being an integral part of both tanks, and with a small solid deorbit motor attached to the tank skirt with a series of struts. The manned module structure is different. It consists of an outer covering of epoxy tiles, a 1.1 cm aluminum pressure vessel, and an inner tantalum barrier, Fig. 5-4, to protect the crew from solar radiation of up to 10^8 protons/cm^2/event.

5.3.1.1 Major Maintenance Concerns. The prime structural maintenance concern is meteoroid damage to the returning core aluminum shell and crew module epoxy tiles. The 1973 Tug studies based on the NASA SP 8013, Meteoroid Environment Model, concluded that the structure LOX and LH_2 tanks can be protected against failure to a probability of less than 0.05, utilizing standard design criteria. Although the design can protect from meteoroid penetration of a sufficient depth to cause failures when superimposed on the applied stress, it is not possible to avoid or predict the damage of a meteoroid encounter.

5.3.1.2 Maintenance Plans. Maintenance plans for the structure would include inspections to check for pitting and cracks in the core structure, or damage to the crew module titles. Non-destructive tests will be made using dye penetrant, ultrasonic and radiographic equipment. OFI tank pressure and temperature information will also be

used to assess the condition of the tanks. Pressure decay tests will be used if there are any pittings or cracks in the structure or questionable OFI LH_2 tank data. In addition, the core and crew modules exterior structures will be mapped to record cumulative flight and handling damage.

Repairs to the core structure can be made in place and crew module damaged tiles can be replaced as required.

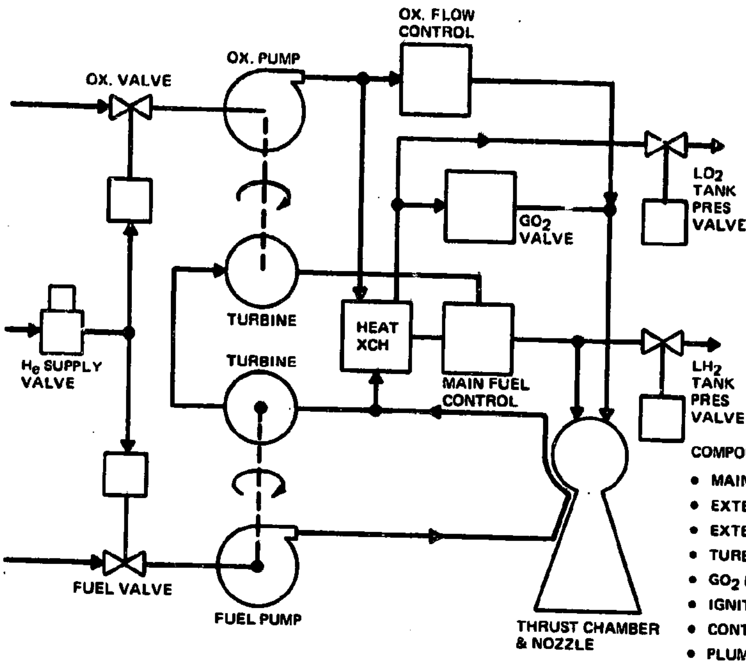
5.3.2 Propulsion System Requirements

The propulsion system discussed in the following paragraphs includes the two main RL10 Cat IIB engines, the ACPS RCS engines, the core fuel tanks, the drop tanks, and the fluid distribution and control systems for the main and RCS engines. The solid drop tank rocket engines are not covered because the drop tank modules are not returned to the maintenance depot and the incoming replacement modules are completely checked out at the factory.

The main propulsion subsystem consists of the main engine vector control servo for both engines, feed purge, relief, vent, propellant pressurization, and conditioning, as illustrated in Figs. 5-6 and 5-7. The ACPS is functionally similar, except that attitude control is achieved by firing selected engines. Figure 5-8 is a functional schematic of the ACPS.

Turnaround requirements for the RL10 engines, the main propulsion system, and the ACPS are summarized in Figs. 5-6, 5-7, and 5-8, respectively. These Figs. include a functional schematic of the system, a listing of the major components and their location, along with a breakdown of the C/O and maintenance requirements. The requirements format is structured to define what has to be done, i.e., the requirement; when the activity should be accomplished; how the task is accomplished; and whether the function is monitored by OFI and an estimate of the time for the function. The time quoted is for the specific function, with no preparation or setup time included.

5.3.2.1 Main Engines, Fig. 5-6. Key maintenance concerns are the condition of the limited life thrust chamber assemblies for the main engines and the main engines turbo pump bearings, turbines, and ignition system. The staged combustion cycle imposes severe demands on the combustion chamber which operates at very high pressures and thermal gradients. The main combustion chamber cooling flow requirements demand very high turbo pump discharge pressures which in turn require extremely high turbo



COMPONENTS

- MAIN CHAMBER & PRIMARY NOZZLE
- EXTENDABLE NOZZLE
- EXTENDABLE ACTUATOR SYS
- TURBO PUMP & GEAR BOX
- GO_2 HEAT EXCHANGER
- IGNITION SYS
- CONTROLS & INSTRUMENTATION
- PLUMBING

TURNAROUND & MAINTENANCE REQT'S	WHEN				HOW					
	POST/ PRE FLT	PERI-ODIC	FLT CRAB	OVER-HAUL	VISUAL	MANUAL	SEMI AUTO	OFI	TIME	REMARKS
1.0 THRUST CHAMBER ASSEMBLY										
1.1 PURGE TANKS & ENGINE (H_2)	X						X		45 MIN	HAZARDOUS
1.2 STRUCT DAMAGE & DEFORMATION INSPECT	X	X	X	X	X	X			45 MIN	
1.3 LOOSE HDW, CRACKS CORROSION	X				X	X			35 MIN	
1.4 FUEL SYS & CHAMBER LEAK CHECKS		X	X	X			X	X	2 HR	VERIFY OFI
1.5 FUEL & O_2 INJECTOR FLOW CHECKS		X	X	X			X	X	45 MIN	VERIFY OFI
2.0 EXTENDABLE NOZZLE ASSEMBLY										
2.1 THERMAL DAMAGE INSPECTIONS	X				X	X		X	15 MIN	VERIFY OFI
2.2 PRESS DECAY LEAK CHECKS			X	X	X	X		X	2 HR	
2.3 FUNCTIONAL			X	X				X	15 MIN	VERIFY OFI
3.0 TURBO PUMP & GEAR BOX ASSEMBLY										
3.1 COMPLETE INSP PARTS WEAR & SEALS		X		X	X	X			2.25 HR	
3.2 LOOSE HDW, THERMAL DAMAGE	X				X				45 MIN	
3.3 INTERNAL & TURBO PUMP INTER STAGE SEAL LEAK CHECKS	X		X	X	X	X			2 HR	
3.4 FUNCTIONAL – PUMP TORQUE & PERFORMANCE CHECKS		X	X	X				X	45 MIN	VERIFY OFI
4.0 GO_2 HEAT EXCHANGER										
4.1 CRACKS, CORROSION, DAMAGE INSP		X			X				30 MIN	
4.2 PRESS DECAY LEAK CHECKS			X	X					1 HR	
5.0 IGNITION SYSTEM										
5.1 SPARK INSPECTION	X				X				15 MIN	
5.2 IGNITION CONTINUITY CHECK			X	X			X	X	15 MIN	VERIFY OFI
5.3 FUEL & O_2 FLOW CHECK			X	X			X	X	30 MIN	VERIFY OFI
6.0 CONTROLS & INSTRUMENTATION										
6.1 LOOSE HDW & DAMAGE INSPECTION	X				X	X			45 MIN	
6.2 FUNCTIONAL CHECKS			X	X				X	45 MIN	VERIFY OFI
6.3 CALIBRATIONS		X	X	X				X	15 MIN	VERIFY OFI
7.0 ENGINE GIMBAL CONTROL										
7.1 INSPECT ACTUATOR MECHANISM	X			X	X				30 MIN	
7.2 FUNCTIONAL CHECK REDUNDANCY	X			X			X	X	15 MIN	VERIFY OFI
7.3 MEASURE ACTUATION LOADS		X	X	X			X	X	30 MIN	VERIFY OFI
8.0 ENGINE REMOVE & REPLACE				X		X			4 HR	

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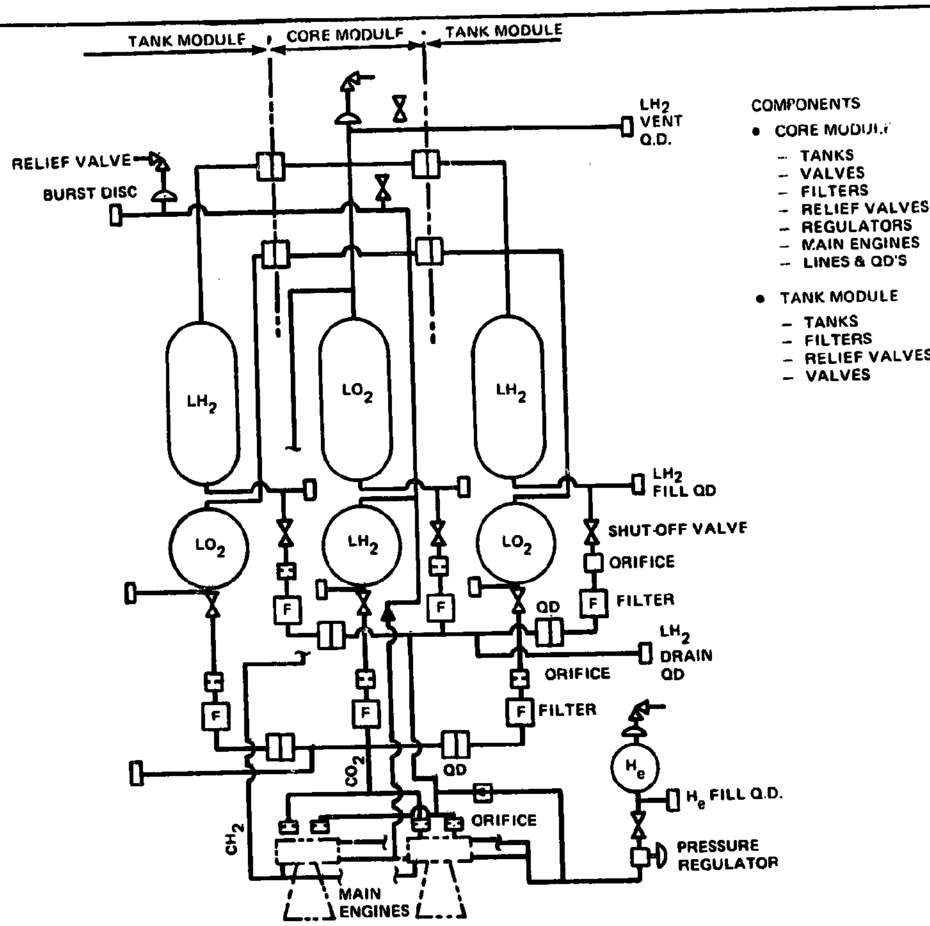
Fig. 5-6 RL10 !I B Main Engine

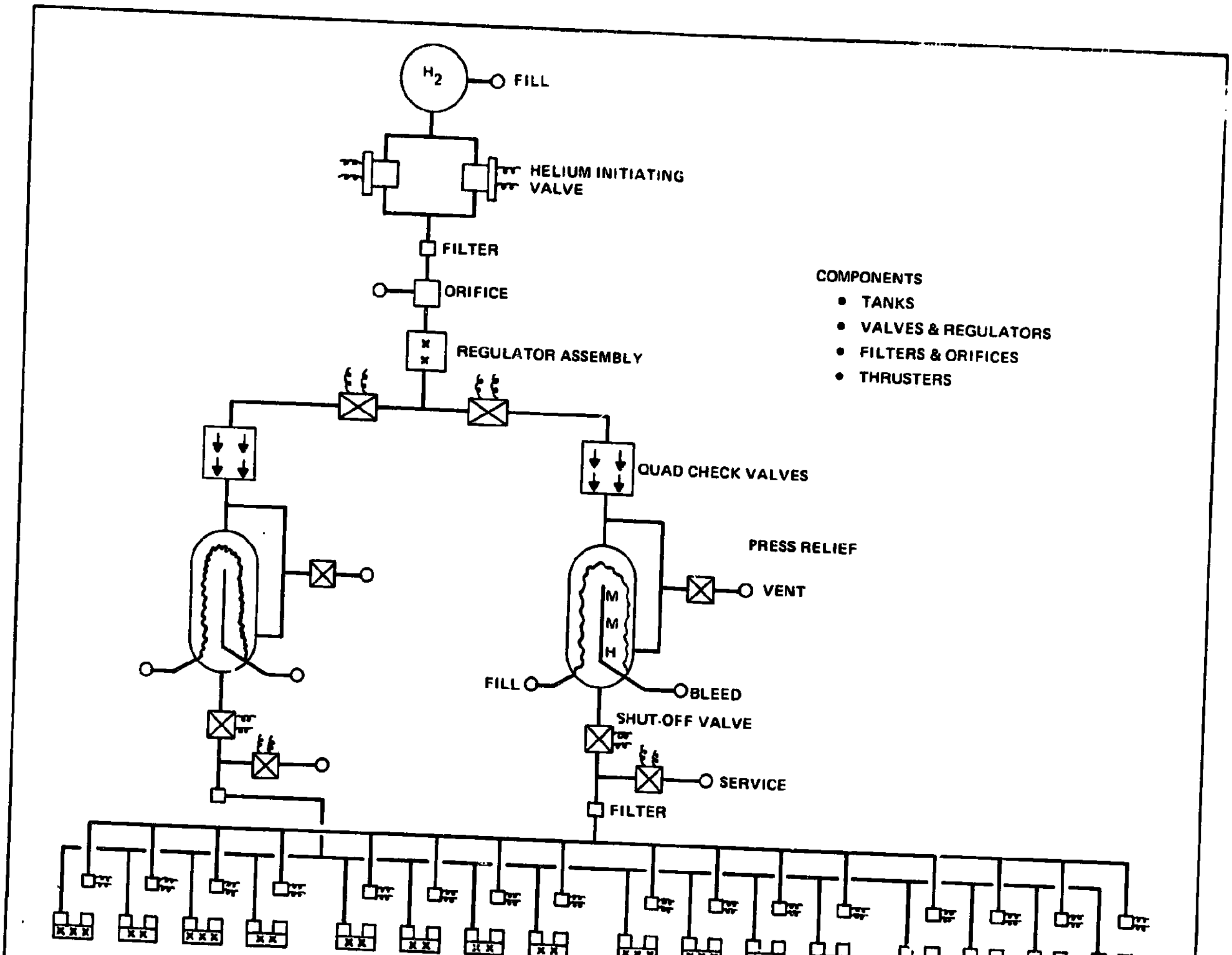


	WHEN				HOW					
TURNAROUND & MAINTENANCE REQ'S	POST/PRE FLT	PERIODIC	FLT CRAB	OVER-HAUL	VISUAL	MANUAL	SEMI AUTO	OFI	TIME	REMARKS
1.0 CORE MODULE										
1.1 PURGE TANKS	X						X		2 HR	HAZARDOUS
1.2 INSPECT FOR LOOSE HDW & DAMAGE	X		X	X	X				30 MIN	
1.3 REFURBISH FILTERS	X			X		X			45 MIN	
1.4 LEAK CHECKS (Q.D'S, COUPLINGS* & VALVES)	X		X	X		X	X		2 HR	QD'S 1 HR, COUPLINGS 30 MIN.
1.5 RELIEF VALVE FUNCTIONAL CHK	X		X	X			X	X	45 MIN	VERIFY OFI
1.6 SYSTEM FUNCTIONAL	X		X	X				X	30 MIN	VERIFY OFI
1.7 INSTRUMENTS CALIBRATION		X		X				X	1 HR	VERIFY OFI
2.0 TANK MODULES										
2.1 INSPECT FOR LOOSE HDW & DAMAGE	X				X				30 MIN	
2.2 LEAK CHECKS	X					X			2 HR	
2.3 FUNCTIONAL CHECKS	X					X		X	30 MIN	VERIFY OFI
2.4 INSTRUMENTS CALIBRATION	X							X	1 HR	VERIFY OFI
3.0 SERVICING	X						X		2 HR	PAD OPS

*UTILIZE VISUAL AIDS PER GROUNDRULE 6.1.2.4

1776-813W

Fig. 5-7 Propulsion System



TURNAROUND & MAINTENANCE REQ'S	WHEN: POST/PRE FLT	PERIODICAL	FLT CRAB	OVER-HAUL	HOW: VISUAL	MANUAL	SEMI AUTO	OFI	TIME	REMARKS
1.0 LEAK & FUNCTIONAL										
1.1 PQMD CALIBRATION			X	X			X	X	30 MIN	VERIFY OFI
1.2 REGULATOR LEAK & FUNCTIONAL	X		X	X			X	X	45 MIN	REG PR OFI
1.3 RELIEF VALVE LEAK & FUNCTIONAL			X	X			X		45 MIN	RELIEF PR OFI
1.4 CONTROL VALVES LEAK & ELECTRICAL			X	X			X	X	3 HRS	CNT'RL SIG OFI
1.5 QUAD CHECK VALVES LEAK & FUNCTIONAL		X	X	X			X		45 MIN	CNTR'L SIG OFI
1.6 FUEL/OXIDIZER TANKS LEAK			X	X			X	X	2 HR	PRESS OFI
1.7 HEATERS FUNCTIONAL		X	X	X			X	X	15 MIN	CNTR'L SIG OFI
2.0 SERVICING										
2.1 PURGE & SAFE	X						X		1.5 HR	
2.2 SERVICE FUEL	X						X		45 MIN	LFS/OFI
2.3 SERVICE HELIUM	X						X		30 MIN	LINE OPERATION
3.0 SYSTEM END TO END LEAK TEST	X		X	X				X	2 HR	

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Fig. 5-8 Attitude Control Propulsion Subsystem

pump rotational speeds and hot gas drive. These high performance demands result in limited cycle/life for the chamber liner, injector, turbo pump bearings, and turbines.

Condition assessment of these critical components is provided in several ways. Both main engines are operational and recorded engine parameters during flight provide sufficient data to give reliable indications of the performance and control of both main engines. Engine sequencing performance and ignition circuit integrity are checked on the ground. Visual inspections are used to determine the condition of the engine components. Purge system internal leak checks and turbo pump interstage seal leak checks round out the routine, per mission, checks used to determine the condition of the main engines.

5.3.2.2 Main Engine Vector Control, Fig. 5-6. Main engine thrust vector control performance can be determined through OFI recorded response to command, gimbal rate, position acceleration, etc. Functional ground tests are used to check redundant motor and drive train operation prior to each flight, and periodic measurement of gimbal actuation loads are used to determine the overall condition of the servo loop.

5.3.3 Propulsion Subystem, Fig. 5-7

The propulsion subsystem includes the core and drop tank feed, fill, drain, vent, and relief lines and associated valving. Propellant feed lines and valves transfer LH_2 or LOX from either of the drop tanks or the core module to the main engines. The fill and drain system provides the interconnect between the ground and the flight tanks through quick disconnects which interface with the Orbiter. Fill and drain operations are controlled through the fluid electrical interface panel in the Orbiter and similar panel in the MOTV. The propellant vent and relief plumbing and valves insure that the pressure in each tank is kept within design limits and may be employed through command to condition the propellants prior to delivery to the engine pump inlet.

The feed, fill, drain, and vent propulsion subsystem valves, tanks, and lines are instrumented to allow thorough evaluation of system and component operation. All redundant paths are operational. Relief valve operation is the only standby function not monitored in flight. Preflight checks include vent and relief valve cracking and reseating pressures and end-to-end leak checks. Interface tests are conducted to check the integration of the tank and core modules.

5.3.4 Attitude Control Propulsion Subsystem (ACPS), Fig. 5-8

The ACPS consists of a Helium pressurization assembly which pressurizes the oxidizer and fuel tank assemblies, and the propellant distribution manifold lines and

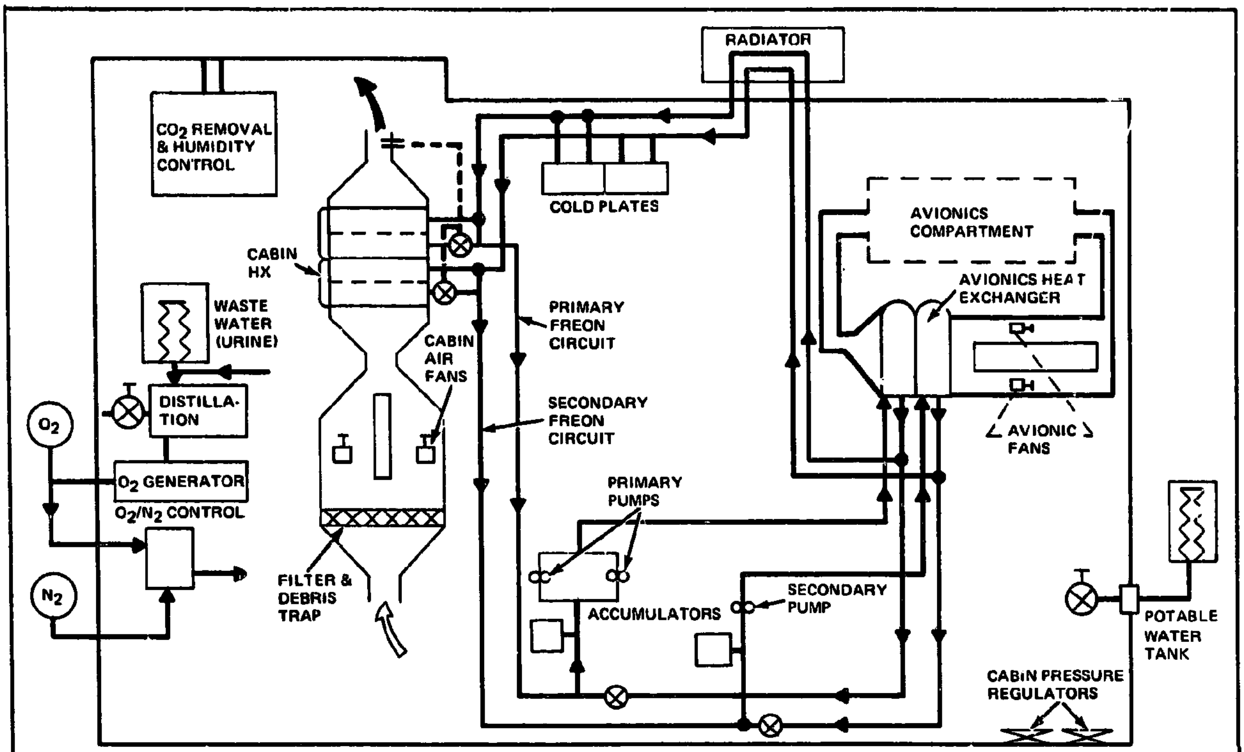
valving which control the flow of oxidizer and monomethyl Hydrazine (MMH) fuel to the thruster assemblies. The attitude control electronics selects the required combination of thrusters to provide attitude control, rotational maneuvering, and translational maneuvering. All valves, tanks, and the distribution system are instrumented to provide in-flight performance data. All thrusters and valves will be actuated in flight, except for the relief valves. These will be checked before each flight for cracking and reseating pressure levels. End-to-end leakage checks will also be conducted prior to each flight. Subsystem and component operational tests will be conducted as required to isolate anomalies and reverify integrity of the subsystem.

The major maintenance concerns are post mission safing of the system and the condition of the thrusters.

The system is purged to remove the hazardous MMH and oxidizer and safe the system. Thrusters are automatically purged since they are vented to space. Prior to docking, the distribution systems between the shutoff valve and the thruster shutoff valves are vented to space through the service port. After docking, the Orbiter purge and pressurization system alternately pressurizes the tanks and vents them to space, leaving a pad pressure in the tanks so they do not collapse during return to earth. A final purge is accomplished on the ground to insure that all hazardous fluids and vapors are removed. Borescope inspections are used to assess the condition of the thrusters after each flight.

5.3.5 Environmental Control Life Support System (ECLSS), Fig. 5-9

The ECLSS consists of a habitation area or cabin; a heat transport section to condition the cabin and avionics; an atmosphere revitalization section to control the quality of the cabin air; and a waste management system to accommodate the crew sanitary needs. In addition, crew provisions have been grouped with the ECLSS. The ECLSS is instrumented to permit condition assessment of the various components based on in-flight performance data. Crew comments are also used to evaluate the condition of the ECLSS subsystem, since there is a direct interface throughout the MOTV mission. Routine maintenance consists mainly of servicing and verifying the integrity of the ECLSS following servicing operations. Component tests are conducted to verify or isolate anomalies and verify operation following corrective action.



TURNAROUND & MAINTENANCE REQ'S	WHEN: POST/PRE FLT	PERIODIC	FLT CRAB	OVER-HAUL	HOW: VISUAL	MANUAL	SEMI AUTO	OFI	TIME HR	REMARKS
1.0 CABIN										
1.1 LEAK CHECK			X	X		X			2.0	FLOW METER
1.2 RELIEF VALVE FUNCT CHECK	X		X	X			X		0.2	VERIFY OFI
2.0 ATMOSPHERE REVITALIZATION SECTION										
2.1 CO_2 REMOVAL ASSEMBLY		X	X	X			X	X	0.5	VERIFY OFI
2.2 O_2 GENERATION ASSEMBLY		X	X	X			X	X	0.5	VERIFY OFI
2.3 CABIN & AVIONICS COOLING ASSEMBLIES			X	X		X		X	0.2	VERIFY OFI
2.4 SERVICE	X								0.5	CHANGE FILTERS, ETC.
3.0 HEAT TRANSPORT SECTION										
3.1 PROOF – LEAK CHECK			X	X		X			2.0	
3.2 DRAIN, DRY, RECHARGE FREON				X		X			24	
3.3 PUMPS CHECKOUT	X					X		X	0.2	VERIFY OFI
4.0 WATER RECLAMATION SECTION										
4.1 SERVICE	X					X			1.0	FILTERS, ETC.
4.2 FUNCTIONAL CHECK	X	X	X			X		X	0.5	VERIFY OFI
4.3 POTABLE WATER TANK – FILL	X					X		X	X	VERIFY OFI
5.0 WASTE MANAGEMENT SECTION										
5.1 SERVICE	X					X			1.0	
5.2 FUNCTIONAL OK	X		X			X		X	0.5	VERIFY OFI
6.0 CREW PROVISIONS										
6.1 FOOD SERVICE	X					X			2.0	
6.2 EMU SERVICE & C.O.	X					X			2.0	
6.3 EVA SUIT C.O.	X					X			1.0	

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Fig. 5-9 ECLS Subsystem

5.3.6 MOTV Avionics

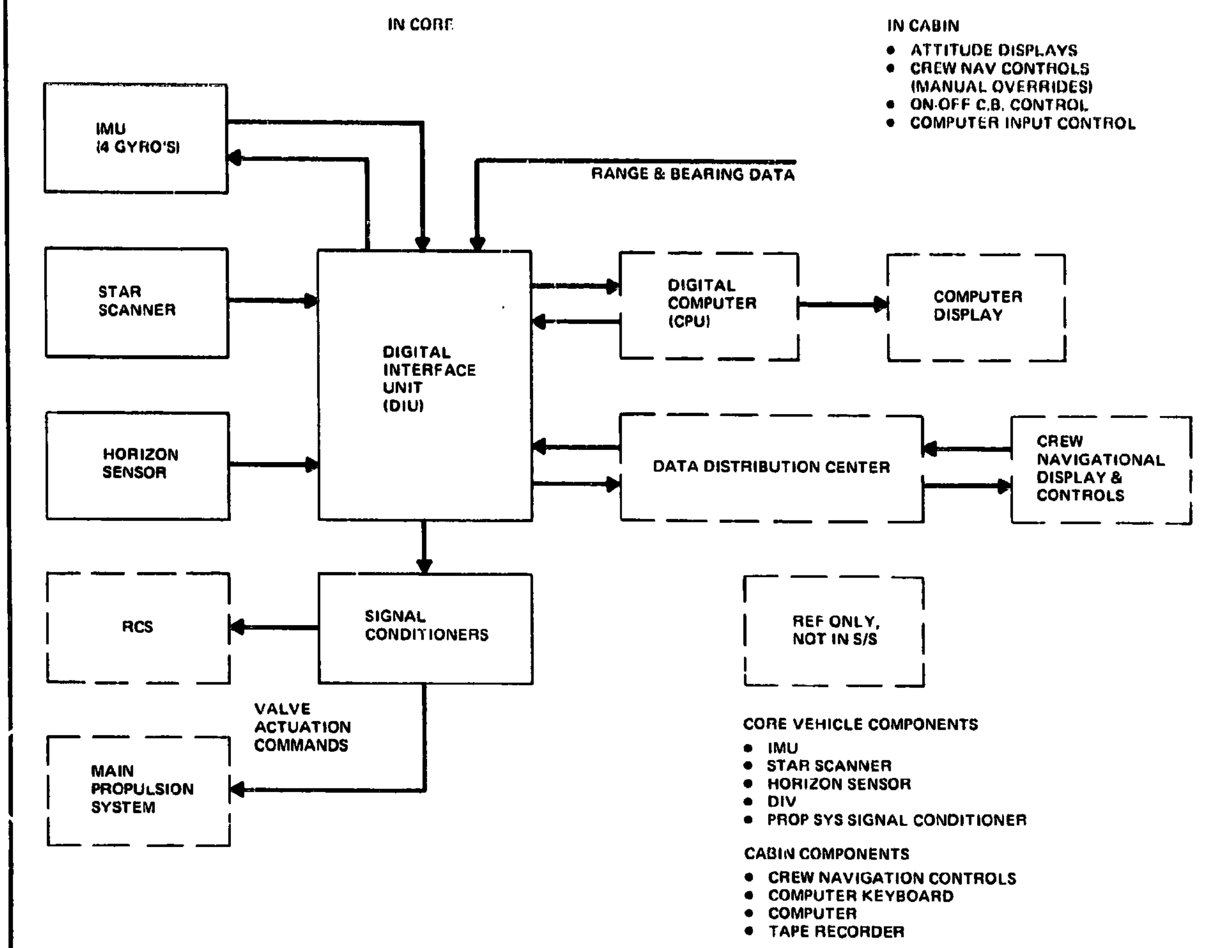
This section covers the maintenance analysis of the MOTV avionics. Included are summary descriptions and functional schematics which include maintenance and C/O requirements for the following subsystems (S/S):

- Attitude control and determination (Guidance & Navigation)
- Rendezvous radar
- Data management
- Tracking, telemetry, and communications
- Operational Flight Instrumentation (OFI)
- Display and control
- Electrical power.

5.3.6.1 Attitude Control and Determination S/S (ACDS), Fig. 5-10. The ACDS consists of three-axis strapdown Inertial Measurement Units (IMU), two axis gimballed star trackers, horizon sensors, a Digital Interface Unit (DIU), and signal conditioners.

During powered flight, the IMU provides vehicle attitude information and incremental velocity change information through the DIU to the digital computer (CPU). Based on the IMU vehicle data, initial deployment data, and programmed mission requirements, the CPU develops flight control vector commands for the main engine, attitude control commands for the RCS, and visual cues for the pilots displays. During coast flight, the star tracker and horizon sensor supplement the IMU and provide the CPU with additional attitude and navigation data. The star tracker provides precise real-time space attitude data to update the IMU. The horizon sensor provides earth local vertical direction and distance data for attitude control and navigation updating. These data are used by the CPU to reduce bias errors and improve navigation accuracy.

The IMU is a strapdown system employing three accelerometers and rate gyros and associated electronics to measure incremental changes in vehicle attitude and velocity. The star tracker is a two-axis gimbal-mounted photoelectric telescope with precision angle pickoffs and associated electronics to provide the precise space attitude data. The horizon sensor is essentially static, maintaining the field of view through a mirror whose motion is used to generate earth local vertical data. Calibration provisions correct for thermal or electronic drift. The DIU provides the interface between the various sensors and the CPU to generate the necessary commands and displays.



TURNAROUND MAINTENANCE REQ'S	WHEN				HOW					
	POST/ PRE FLT	PERIODIC	FLT CRAB	OVER-HAUL	VISUAL	MANUAL	SEMI AUTO	OFI	TIME	REMARKS
1.0 IMU TESTS										
1.1 IMU PWR UP & PROGRAM LOAD CHECK			X	X			X	X	30 MIN	VERIFY OFI
1.2 IMU CALIBRATION	X		X	X				X	30 MIN	REQUIRES REMOVAL
1.3 ATTITUDE HOLD/POLARITY CHECK			X	X				X	15 MIN	REQUIRES REMOVAL
1.4 IMU SELF TEST FUNCTIONAL	X							X	15 MIN	REQUIRES REMOVAL
2.0 STAR SENSOR TESTS										
2.1 CALIBRATION			X	X				X	30 MIN	REQUIRES REMOVAL
2.2 SELF TEST FUNCTIONAL	X							X	15 MIN	REQUIRES REMOVAL
3.0 HORIZON SENSOR										
3.1 ATTITUDE HOLD/POLARITY CHECK			X	X				X	15 MIN	REQUIRES REMOVAL
3.2 CALIBRATION	X							X	15 MIN	REQUIRES REMOVAL
3.3 FUNCTIONAL										
4.0 FLIGHT RECORDER FUNCTIONAL & QUALITY CHECKS			X	X					15 MIN	LPS MONITOR & CONTROL

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Fig. 5-10 Navigation & Guidance Subsystem (ACDS)

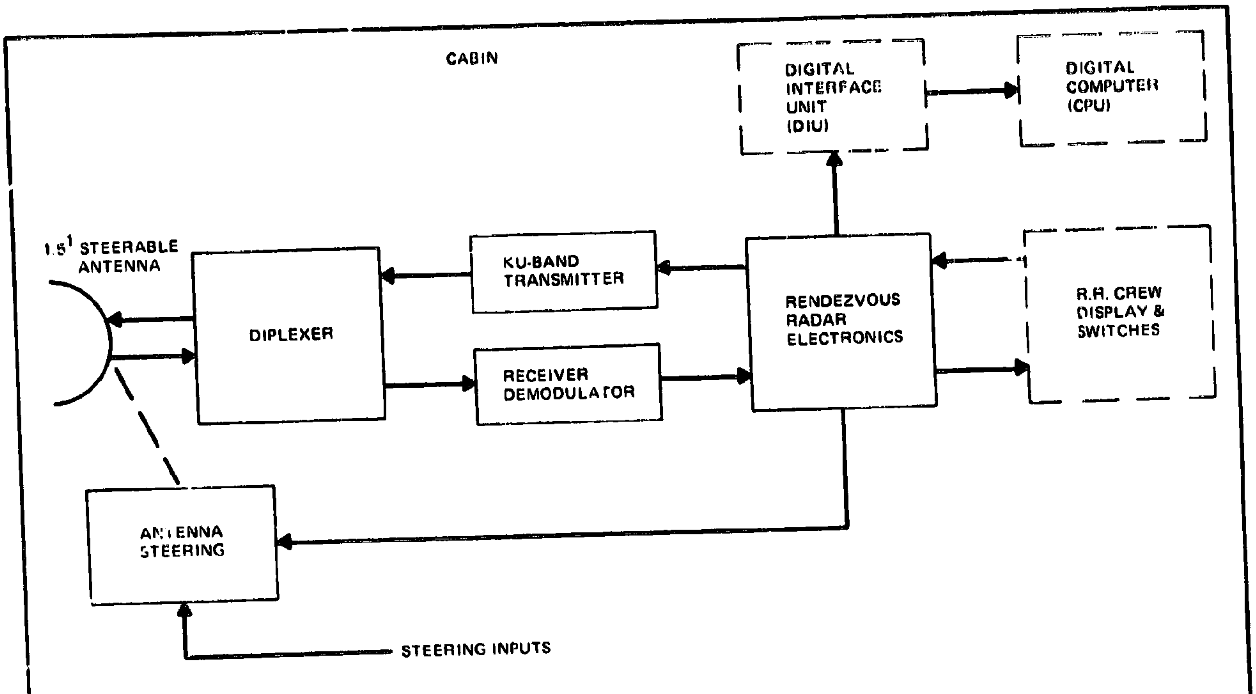
5.3.6.2 Rendezvous Radar S/S Fig. 5-11. This subsystem acquires and tracks cooperative and passive targets assisting MOTV rendezvous with manned or unmanned satellites; it is also used for MOTV to Orbiter rendezvous. The radar detects and locates the target, providing range and steering data for navigation to the target. During final approach this system measures the relative flight variables, i.e., range, centerline deviations, and closing velocity.

The rendezvous radar consists of a 1.5-foot steerable antenna, a duplexer to accommodate received and transmitted signals, the KU-Band transmitter and receiver demodulator, and the rendezvous radar electronics to process and condition the data. Outputs of the electronics package feed the crew displays, the CPU, and an antenna feedback steering loop. Redundancy considerations are consistent with program reliability requirements.

5.3.6.3 Data Management Subsystem (DMS), Fig. 5-12. This subsystem consists essentially of interface and signal conditioning components which collect and condition the signals from the other subsystems for routing to the data distribution center, the computer, and displays which are part of the controls and displays subsystems.

This subsystem accepts status inputs from the various electronic subsystems, main engine, ACPS, fuel distribution system, and the drop tanks. These status inputs are conditioned and converted from analog to digital inputs. An electronic commutator samples the status inputs, and these are applied to the Pulse Code Modulation (PCM) electronics. The output of the PCM electronics is a data stream that is transmitted to the ground via the Data Distribution Center and the TT&C S/S. Conditioned Status Inputs are also used by the Caution and Warning Electronics (C&WE) to drive the C&W displays that are seen by the crew in the cabin. Bio-Med Inputs and ECLSS Inputs are generated for display in the cabin and for transmission to the ground. A tape recorder is provided to work in conjunction with the Data Distribution Center to record data and voice, and to play back this information to the ground when required.

5.3.6.4 Tracking, Telemetry, and Command (TT&C) Fig. 5-13. This subsystem provides the various RF communication links required to support the MOTV missions, and processes and distributes ground or orbiter command signals. Also, the TT&C S/S provides a turnaround ranging signal for tracking the MOTV by ground stations using the S-Band RF Link carriers. Audio/voice communication is provided among crew stations within the MOTV and to manned IVA operation via the RF link. In addition, this S/S generates, transmits and distributes Closed Circuit Television (CCTV) and generates and transmits color TV or CCTV to the ground via the RF link.



TURNAROUND MAINTENANCE REQ'S	WHEN: POST/PRE FLT	WHEN: PERIODIC	WHEN: FLT CRAB	WHEN: OVER-HAUL	HOW: VISUAL	HOW: MANUAL	HOW: SEMI AUTO	HOW: OFI	HOW: TIME	REMARKS
1.0 ANTENNA SERVO 1.1 INSPECTION 1.2 SLEWING	X		X X	X X	X		X	X	30 MIN 15 MIN	
2.0 TRANSMITTER & RECEIVER 2.1 INSPECTION 2.2 VSWR 2.3 TRANSMITTER POWER/PERFORM 2.4 RECEIVER NOISE/SENSITIVITY 2.5 TRANS & RECEIVER FREQ TESTS	X		X X X X X	X X X X X	X		X X X X	X X X X	15 MIN 30 MIN 15 MIN 15 MIN 15 MIN	
3.0 RR ELECTRONICS 3.1 INSPECTION 3.2 RADAR RANGING 3.3 PWR SUPPLY REGULATION 3.4 OVERALL PERFORMANCE	X		X X X X	X X X X	X		X X X	X X X	30 MIN 15 MIN 15 MIN 15 MIN	

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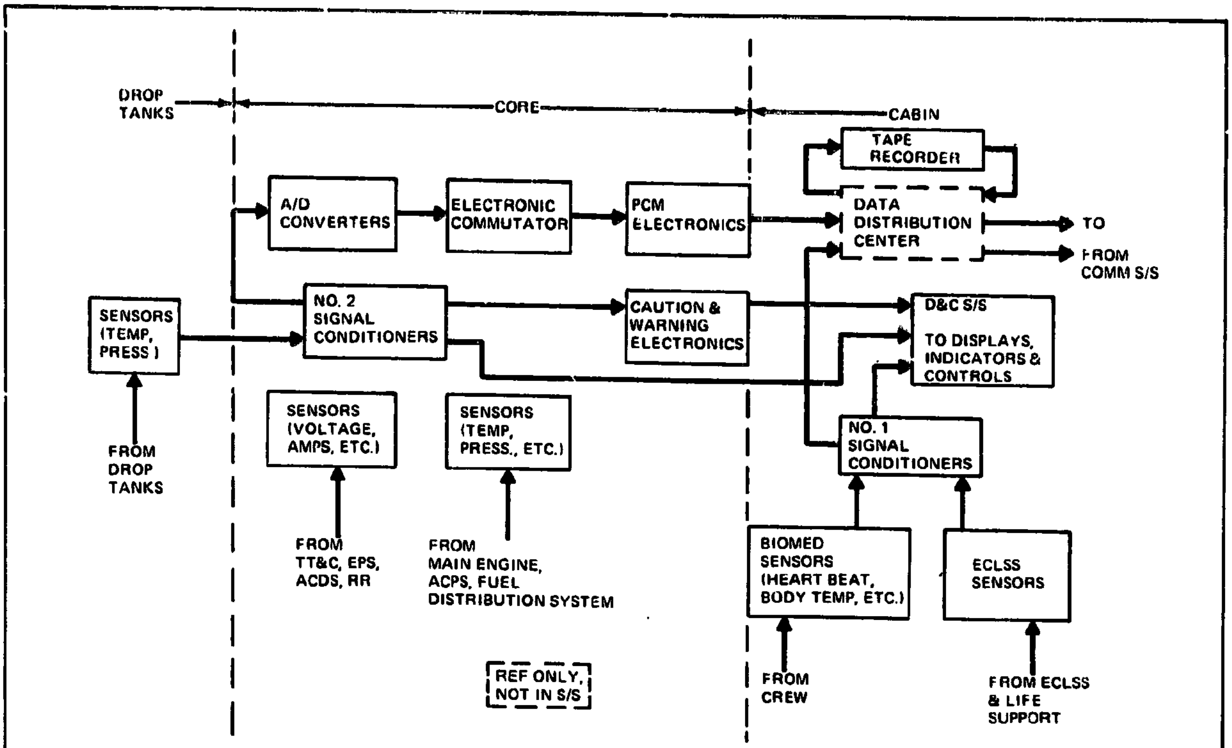
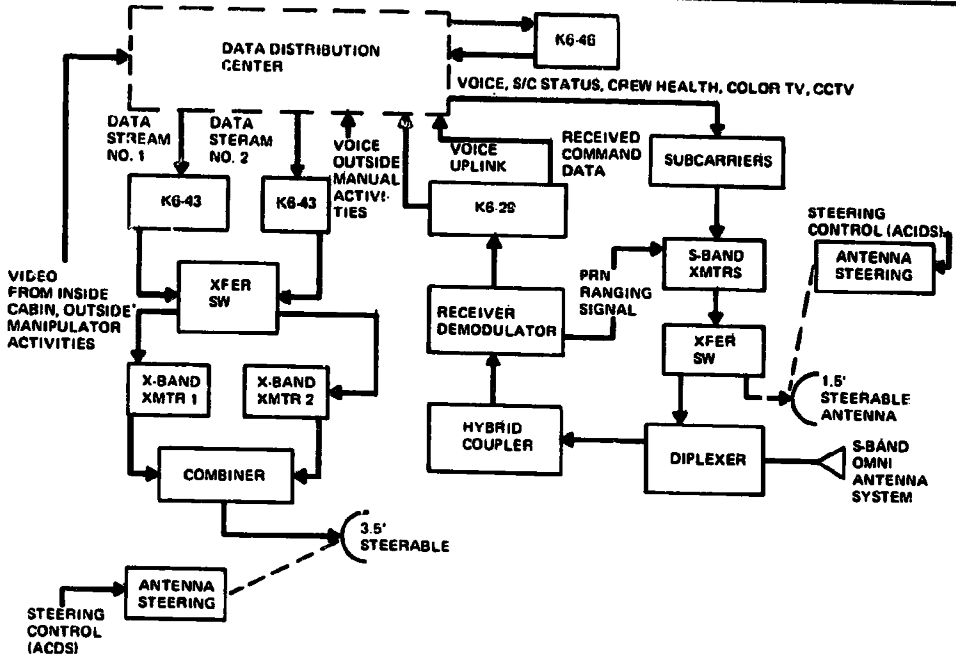
Fig. 5-11 Rendezvous Radar



	WHEN				HOW					
TURNAROUND MAINTENANCE REQ'S	POST/ PRE FLT	PERIODIC	FLT CRAB	OVER-HAUL	VISUAL	MANUAL	SEMI AUTO	OFI	TIME	REMARKS
1.0 SENSORS										
1.1 VISUAL INSPECTION OF TEMP & PRESS. SENSORS		X	X	X	X				2 HR	
1.2 CALIBRATION OF ALL SENSORS		X	X	X			X	X	3 HR	SOME OFF LINE ALL DONE EVERY 5TH FLT
2.0 SIGNAL CONDITIONING & CONVERSION										
2.1 INSPECTIONS	X		X	X	X				1 HR	
2.2 SELF TEST	X		X	X			X	X	15 MIN	
2.3 PERFORMANCE TEST			X	X			X	X	30 MIN	UNDER COMPUTER CONTROL
3.0 FLIGHT RECORDER										
3.1 INSPECTION		X	X	X	X				30 MIN	
3.2 QUALITY CHECK		X	X	X			X		30 MIN	OFF LINE TEST
4.0 PCM ELECTRONICS										
4.1 INSPECTION	X		X	X	X				30 MIN	
4.2 SELF TEST	X		X	X			X	X	15 MIN	
4.3 PERFORMANCE TESTS			X	X			X	X	15 MIN	UNDER COMPUTER CONTROL

1776-818W

Fig. 5-12 Data Management Subsystem



COMPONENTS

- X-BAND (IN CORE)
  ENCODER (MILITARY)
  RF XFER SWITCH
  TRANSMITTERS
  COMBINER
  STEERABLE ANT.
- S-BAND DOWN LINK
  ENCRYPTOR (MILITARY)
  S/C SUB CARRIER OSC (SCO)
  CREW HEALTH SCO
  VOICE SCO
  TRANSMITTERS
  RF TRANSFER SW
  FIXED 1.5' D ANT.
- S-BAND UPLINK
  DESCRIPTOR (MILITARY)
  DIPLEXER
  HYBRID COUPLER
  RECEIVER DEMAND
  OMNI ANTENNA

DISPLAYS & CNTR'LS

- MIC'S & HEAD SETS
- CONTROLS & DISPLAYS

	WHEN				HOW					
TURNAROUND MAINTENANCE REQ'S	POST/ PRE FLT	PERIODIC	FLT CRAB	OVER-HAUL	VISUAL	MANUAL	SEMI AUTO	OFI	TIME	REMARKS
1.0 X-BAND										
1.1 INSPECT FOR DAMAGE & LOOSE PARTS	X				X				30 MIN	
1.2 VSWR & INSERTION LOSS CHECK			X	X			X		1 HR	
1.3 XCVR PERFORMANCE VERIF		X	X	X				X	15 MIN	PERFORMANCE
1.4 FUNCTIONAL	X						X	X	15 MIN	PARAMETERS OFI
2.0 S-BAND										
2.1 INSPECT FOR DAMAGE & LOOSE PARTS	X				X				45 MIN	
2.2 VSWR & INSERTION LOSS CHECK			X	X					1 HR	
2.3 XCVR PERFORMANCE VERIF		X	X	X				X	15 MIN	PARAMETERS OFI
2.4 FUNCTIONAL	X							X	15 MIN	
3.0 PSEUDO-RANDOM NOISE RANGING										
3.1 CALIBRATION		X	X	X				X	30 MIN	PARAMETERS OFI
3.2 FUNCTIONAL	X						X	X	15 MIN	
4.0 CABIN CONTROL CENTER										
4.1 FLIGHT RECORDER TEST			X	X					15 MIN	
4.2 ORB/GND LINK COMPAT TEST			X	X			X		15 MIN	LPS MONITOR & CONTROL
4.3 MOTV/EVA/ORB/GND LINK TEST			X	X			X		15 MIN	
4.4 SYSTEM FUNCTIONAL	X						X		15 MIN	

1776-819W

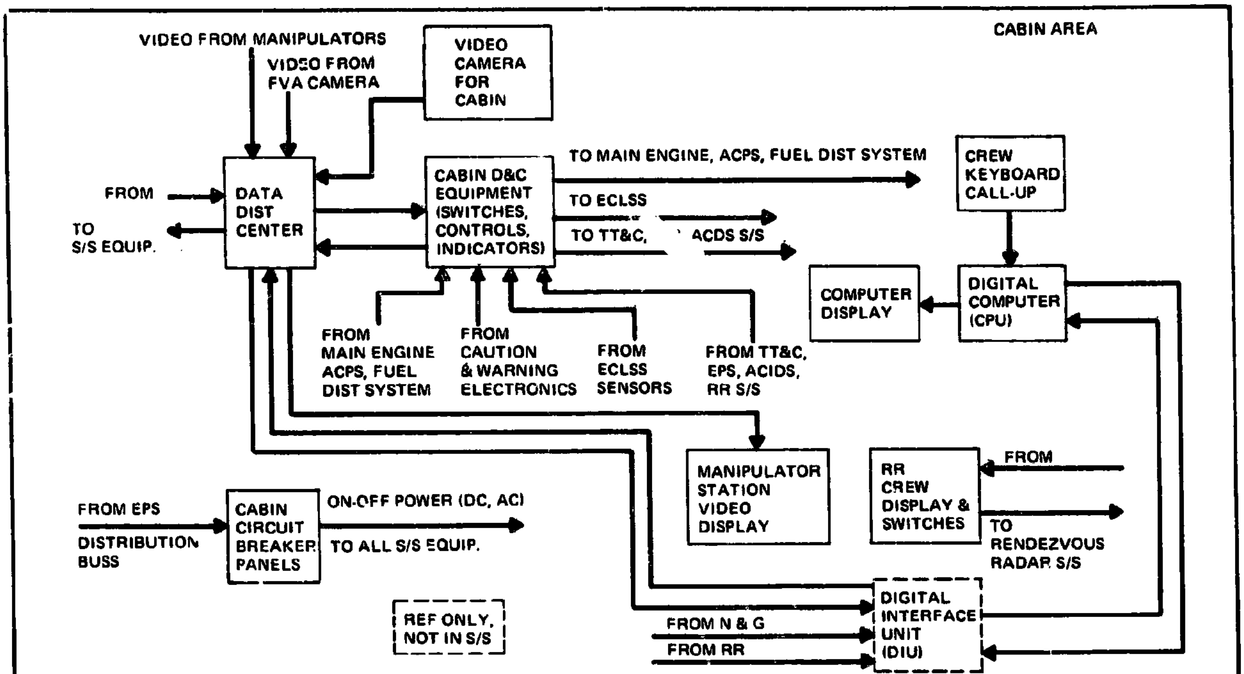
Fig. 5-13 Tracking, Telemetry, and Command

The TT&C consists of two RF links to the ground, S-Band and X-Band. Both systems include steerable antennas, multiple transmitters, receivers, couplers, and demodulators for transmission, receipt, and processing of external signals. The S-Band is used for voice communications and low bit data transmission to the ground or the Orbiter. The S-Band also provides a ground command and data uplink for transmission to the MOTV. Commands are sent up at the crew's request, during the crew's sleeping period or in the crew's absence. Data would be sent up for software program and guidance parameter updates. The X-Band system is used to transmit color TV or other data requiring high data bit rates.

5.3.6.5 Display and Control S/S, Fig. 5-14. The Displays and Controls S/S is the crew interface with the rest of the MOTV subsystems. It has dedicated switches, controls, and instruments to monitor, command, and control all the vehicle subsystems during the operation of the MOTV. There are duplications of displays and controls to permit the vehicle to be piloted from either the pilot or copilot stations. Automatic and manual control capability is provided for all mission phases except docking, which is manual only. Circuit breakers are also provided for control of the AC and DC power to all subsystems. A caution and warning display is used by the crew for malfunction identification. In the Display and Control S/S, a computer CRT display is provided along with a keyboard for entrance into the digital computer for desired vehicle information and data. Finally, there is a CCTV display that is used in conjunction with the manipulators during IVA operation.

5.3.6.6 Operational Flight Instrumentation (OFI). Operational Flight Instrumentation is the key to the condition monitoring philosophy recommended for the MOTV. It is not a separate subsystem but simply the combination of sensors, distribution, signal conditioners, computer, software, and RF transmission components which are elements of the avionics subsystems already discussed.

OFI data are developed in the Data Management Subsystem where vehicle sensors are sampled electronically and sent to the PCM electronics. The Pulse Code Modulation (PCM) Electronics generates a data stream which goes to the Data Distribution Center for transmission to the ground via the Tracking, Telemetry, and Command (TT&C) Subsystem. In addition, the crew can use the keyboard for calling up the OFI data from the digital computer and have this information displayed on the computer CRT display. The digital computer stores the OFI data via the Data Distribution Center and the Digital Interface Unit in the ACDS Subsystem.



	WHEN				HOW					
TURNAROUND MAINTENANCE REQ'S	POST/ PRE FLT	PERIODIC	FLT CRAB	OVER-HAUL	VISUAL	MANUAL	SEMI AUTO	OFI	TIME	REMARKS
1.0 VIDEO EQUIPMENT										
1.1 VISUAL INSPECTION	X		X	X			X			
1.2 PICTURE QUALITY TEST	X		X	X			X		30 MIN	OFF LINE TESTS
1.3 FUNCTIONAL TEST	X		X	X			X	X		
2.0 COMPUTER/COMPUTER DISPLAYS										
2.1 SELF TEST	X								15 MIN	
2.2 COMPUTER PERFORMANCE	X								–	THROUGH C/O
2.3 CPU TIMING, REGISTER, ARITH LOGIC, INTERRUPT LOGIC, I/OC			X	X			X	X	30 MIN	VIA GRD COMPUTER
2.4 INPUT OUTPUT CONTROLER TRAFFIC CONTROL			X	X			X	X	15 MIN	VIA GRD COMPUTER
2.5 MAIN MEMORY ACCESS, READ, WRITE & STORAGE			X	X			X	X	15 MIN	VIA GRD COMPUTER
2.6 CRT PERFORMANCE			X	X			X		15 MIN	
3.0 CONTROLS & DISPLAYS	X									THROUGH C/O

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Fig. 5-14 Crew Module Displays and Controls

5.3.6.7 Electrical Power Subsystem (EPS), Fig. 5-15. The EPS for the S-1 mission consists of a power distribution section and power generation section. The power distribution unit provides for the protection, control, switching, and distribution of power to the MOTV subsystems. It also provides isolation and circuit protection for the Orbiter standby power feed to the main bus. This unit contains the circuit breakers, solid state voltage sensors, and internal/external power controllers to provide circuit protection between the main power bus and each subsystem distributor, and between the Orbiter power line and the MOTV power bus.

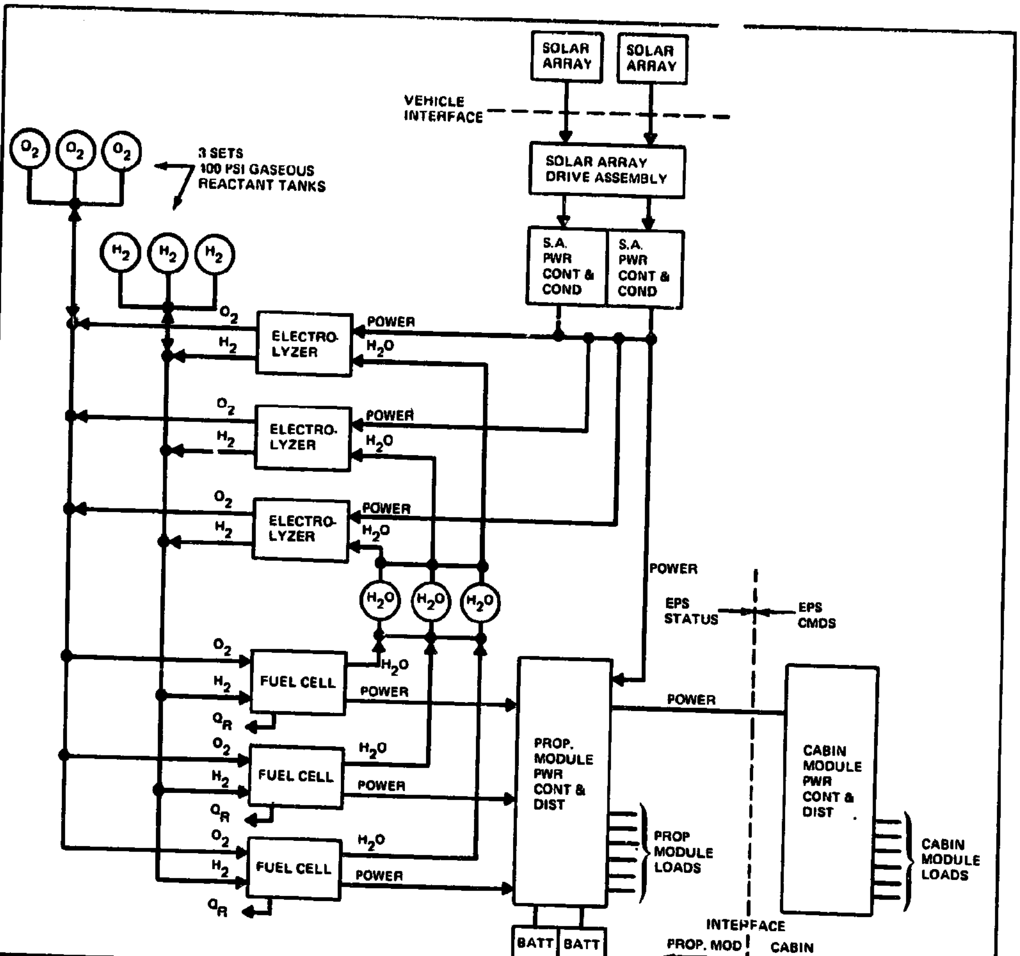
The power generation section can be configured for fuel cell power or fuel cell plus solar cell power. The configuration decision for the next flight is made on the basis of projected mission power requirements. Reconfiguration is a scheduled ground maintenance task.

For power requirements $\leq$ 800 KWHR, which includes a 50% redundancy factor, the fuel cell plus the peak load battery is flown because of its weight advantage. Characteristically, fuel cell power has a flat voltage response to the load change and a long life, which facilitate voltage regulation and enhance reliability. The fuel cells utilize propulsion grade reactants extracted from the H_2 and O_2 tanks and produce electrical power, heat, and water. The water is potable and is used in the ECLSS, while the heat is dissipated through the radiators located in the core. AgZn batteries are used in conjunction with the fuel cells to accommodate peak loads.

For power requirements > 800 KWHR, a 12 KW solar array is installed on the core module. Also added are electrolyzer units to break down the water to O_2 and H_2, which replenish the reactant tanks making the power generation a closed loop regenerative system which also reduces the number of reactant tanks required. The AgZn batteries are still used for peak loads and could also be used as emergency backup power.

The OFI fuel cell stack voltage, stack current, and condenser subcooler inlet and outlet temperature flight data, coupled with visual inspections of the components and connections, are sufficient to verify the flight readiness of the fuel cells. The solar arrays will be removed and checked in the lab between flights. The major maintenance concern is reconfiguration and verification.

5.3.6.8 Avionics Maintenance. The avionics maintenance plan is to rely primarily on the flight information available from the last mission, plus scheduled inspections and checks to detect anomalies. Following completion of troubleshooting, replacement, and



TURNAROUND MAINTENANCE REQ'S	WHEN: POST/PRE FLT	WHEN: PERIODIC	WHEN: FLT CRAB	WHEN: OVER-HAUL	HOW: VISUAL	HOW: MANUAL	HOW: SEMI AUTO	HOW: OFI	HOW: TIME (HR)	REMARKS
SUBSYSTEM										
INSPECT COMPONENTS	X		X		X				1	
FUNCTIONAL, REDUNDANCY VERIFICATION	X		X	X			X	X	3	
SERVICE	X					X	X		1	REACTANT, WATER BATTERY
FUEL CELL/ELECTROLYZER										
START UP & PERFORMANCE TEST		X	X	X			X	X	2	
REACTANT & WATER CONTROLS & LEAK TEST		X	X	X		X	X	X	2	
MECHANICAL, THERMAL INTERFACE CHECK		X	X	X	X		X	X	1	
REPLACE FUEL CELL/ELECTROLYZER				X		X			2	40,000 HR LIFE-LIMITED
REPLACE REACTANT/WATER TANK				X		X			2	
SOLAR ARRAY										
SOLAR ARRAY DEPLOY/RETRACT & ELECTRICAL CHECK				X	X		X		0.5	OFFLINE
SOLAR ARRAY CONTROL & CONDITIONING CHECK			X	X			X	X	0.5	
SOLAR ARRAY DRIVE/POWER TRANSFER MECH & ELECT. CHECK			X	X	X		X	X	0.5	
REPLACE SOLAR ARRAY		X		X		X			1	GRACEFUL DEGRADATION (LIMITED LIFE)
BATTERY										
RECONDITION, ELECTRICAL PERFORMANCE TEST	X		X	X		X	X	X	6	NON-RESTRICTIVE TASK
REPLACE BATTERY		X		X		X			1	LIFE-CYCLE LIMITED
POWER DIST & CONTROL										
POWER CONTROL/ISOLATION CHECKS		X	X	X			X	X	0.5	
POWER INSTRUMENTATION C/O		X	X	X			X	X	0.5	

1776-82 IW

Fig. 5-15 Electrical Power Subsystem (EPS)

refurbishment, subsystem and system tests will be conducted to verify the flight readiness of the MOTV.

Scheduled maintenance items are defined for each subsystem in the maintenance requirements sheets, Fig. 6-4 through 6-10. Essentially the scheduled maintenance consists of:

- Evaluation of OFI operational performance in-flight data
- Thorough visual inspection of components for security of mounting and condition
- Removal and replacement or refurbishment of time limited items
- Comprehensive tests which are conducted late in the maintenance cycle after anomalies have been corrected because
  - the majority of deficiencies are expected to be identified from flight data
  - the overall maintenance activity on avionics and other MOTV subsystems will impact the integrity of the avionic subsystems
  - corrective action for avionics components can normally be readily accomplished and will have minimal impact on the turnaround schedule even if first detected late in the cycle.

Removals and replacements. Scheduled removals and replacements are the major avionics maintenance concern because they introduce the possibility of inadvertent damage to other nearby equipment and violate the integrity of the subsystem. Reconfiguration of the EPS power generation section is at the top of the list because of installation or removal of the solar array, the electrolyzer, and reactant tanks. Other avionics components requiring periodic removals are:

- TV lamps - each mission due to limited life
- IMU - each mission for calibration
- Transducers - one-fifth of all transducers that cannot be calibrated in place are removed after each flight, providing calibration of all transducers every fifth flight
- Batteries - a freshly charged battery is installed for each flight
- Fuel cells - replacement of fuel cells every tenth mission
- Solar Array - removal for lab electrical and deployment tests.

Post maintenance integrated tests. The final integrated tests conducted after scheduled and unscheduled maintenance has been completed are conducted with ground power and with the aid of built-in test routines or test routines provided by the LPS. These test routines include the capability to verify functional performance of individual components through composite and integrated system tests. Thresholds can be verified by providing stimuli at levels both below and above the specified threshold values and verifying through appropriate response, i.e., switching, gimballing, etc.

The normal proposed sequence of tests is to bring up power, check out the caution and warning circuits, the CRT and computer interface, and then branch out checking out the other subsystems in a series parallel operation through end-to-end and subsystems tests.

The effects of earth rates and gravity can be used to excite the IMU components, thus providing effective end-to-end continuity and polarity tests. Special targets can be used to excite the input to the star tracker and horizon sensor. Ground tests of the RR can be accomplished with antenna hats and test equipment that measures the quality of the output and introduces time-delayed return signals to evaluate range computations.

During these final systems tests, commands are sent to the main engine vector control servos and the individual RCS thrusters. ECLSS functional tests are also conducted at this time. For the final systems verification test, flight software required for the next mission is loaded and checked and an abbreviated mission simulation test is conducted. Successful completion of the systems tests will verify the MOTV flight readiness. Final tests also include integrated C/O of the drop tank modules scheduled for the next mission.

5.4 MOTV KSC TURNAROUND FLOW (HANDLING & TRANSPORTATION REQUIREMENTS)

5.4.1 Core Module Recycling

On return from LEO, the Orbiter with the MOTV Core Module as cargo will land on the KSC runway, undergo safing procedures, and be towed to the Orbiter Processing Facility (OPF). The cargo bay doors will be opened, the strong back attached to the Core Module, and the Core Module transferred to the Payload Cannister mounted horizontally on its Transporter.

The Transporter is moved to the Vertical Assembly Building where the Payload Cannister is rotated to the vertical, and then continues on to the Vertical Processing

Facility. It is moved adjacent to the Payload Ground Handling Mechanism (PGHM), the Cannister is hoisted into position in the PGHM, and the Core Module is removed and mounted in the cell. The Cannister is then returned to the Transporter, and the Transporter moved out of the VPF.

The MOTV Core Module is then picked up in a vertical attitude by the overhead crane and moved to the Integrated Workstand where it will be inspected, and scheduled plus unscheduled maintenance performed. This sequence and the integrated stand are shown in Figs. 5-16 and 5-17.

5.4.2 Drop Tank Delivery

Drop Tanks will be delivered to KSC from the factory by means of the Guppy Aircraft. They will be removed from the Guppy by means of a Cargo Loader Vehicle and transferred to the VPF on the Drop Tank Transporters. At the VPF they will be rotated to the vertical, utilizing the overhead crane and the pivot points built into the Transporters. They will then be transferred to the Integrated Workstands, where interfaces with the Core Module verified, and physical, fluid, and electrical inter-connections will be made.

5.4.3 Pre-Launch Preparation

The GSE will be connected to the Integrated MOTV and a complete checkout and verification of the integrated vehicle will be conducted. The Core Module will then be separated from the drop tanks, moved back into the VPF Cell, and serviced with all but the cryogenic fluids.

The Transporter with the Payload Cannister positioned vertically is then moved back into the VPF and parked adjacent to the C/O cells. The Cannister is then moved to the PGHM, the Core Module installed therein and the Cannister positioned vertically on the Transporter. The Transporter with the Core Module installed in the Cannister is then moved to the PCR at the Launch Pad and the Core Module transferred to the Orbiter Cargo Bay. A final checkout is conducted, cryogenics loaded onboard, and the Orbiter is launched into LEO.

In a similar manner, the Drop Tanks are each moved to the VPF cells, loaded in the Payload Cannister, transferred to the Shuttle Orbiter at the Launch Pad, and each launched in turn into LEO.

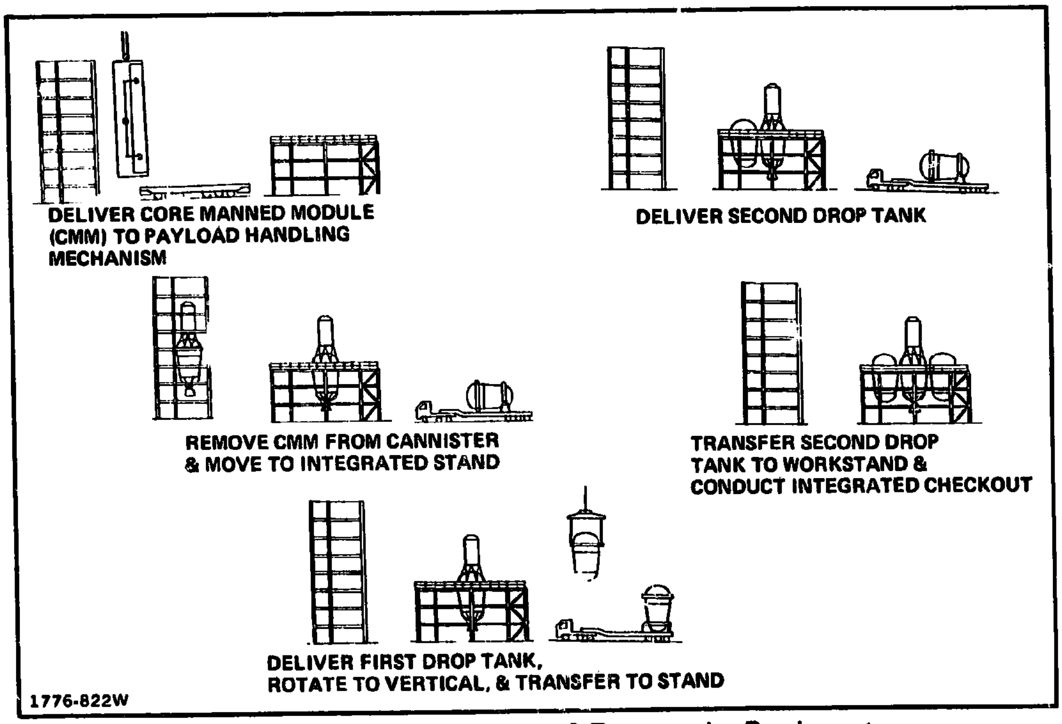


Fig. 5-16 Ground Turnaround Handling & Transportation Requirements

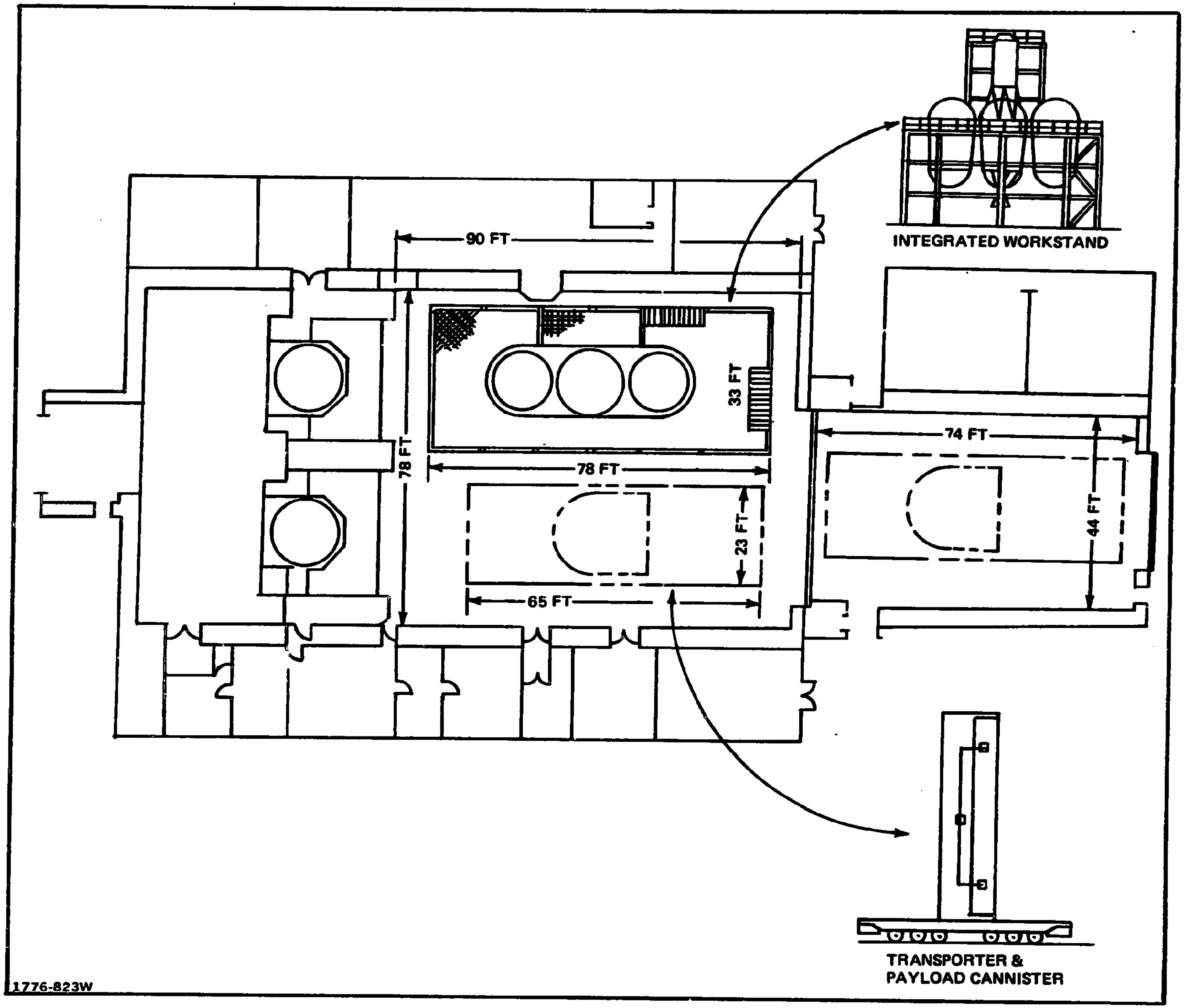


Fig. 5-17 Vertical Processing Facility MOTV Integrated Workstand

5.5 GROUND-BASED MOTV TURNAROUND REQUIREMENTS

The approach used to develop the ground turnaround requirement features extensive use of flight data and inspection to assess the condition of the returning MOTV (Fig. 5-2, paragraph 5.1.4), followed by both scheduled and unscheduled (corrective) maintenance, and concluded by a computer-controlled full up integrated C/O to verify flight readiness, see Fig. 5-2 and paragraph 5.1.4. The functional requirements are responsive to the subsystem requirements discussed in paragraph 5.3 and the groundrules defined in paragraph 5.5.1.

5.5.1 Groundrules

The groundrules and assumptions governing the ground-based turnaround analysis include the following facts.

5.5.1.1 General. The general groundrules are as follows:

- The 1½ Stage All Propulsive MOTV Configuration for the S-1 mission, Fig. 5-4, is the configuration baseline
- The launch site is KSC and the orbital transportation vehicle is the standard STS
- MOTV turnaround will be conducted within the Shuttle schedule operational and safety constraints
- Scheduled turnaround processing and maintenance operations will be conducted on an eight-hour, single shift, five-day-a-week basis
- Unscheduled maintenance and contingencies will be handled on a two, eight-hour shift, five-day-a-week basis
- OFI through the onboard computer can exercise and monitor most functional systems including redundant paths
- Ground data processing computer programs will corrolate and compare flight and ground test data with component trend data and flag deviations
- Turnaround operations will include the turnaround and processing of returning core/manned module and incoming tank modules through integration with the orbiter including launch support.

5.5.1.2 Propulsion. The propulsion groundrules are as follows:

- OFI data provide a complete status of the health and operation of the propulsion systems; they are recorded and can be telemetered to the ground for condition assessment
- All main engine parallel redundant paths are "on line" and can be checked in flight
- Welding is the primary method for connecting fuel lines to each other and to valves; tanks are also weldment assemblies; inter-module connections are of the quick disconnect self sealing type
- Leak detection tape or elastomeric paint is applied to all potential leakage connections except the QD's
- All components except the thrust chambers and turbo pumps are line replaceable units (LRU)
- Provisions for internal inspection of the main engine thrust chamber and turbo pump components are available
- All components except the thrust chambers, turbo pump, and ignition system have a time/life cycle good for 15 missions.

5.5.1.2 Avionics. The avionics groundrules are as follows:

- All avionics subsystems are instrumented adequately to provide in-flight operational performance data
- Calibration and adjustment can be accomplished without component removal, except for the IMU
- Data from checkout, fault isolation, status, and flight are transmitted to ground computer and are available for maintenance analysis.

5.5.2 Ground-Based Turnaround Scenario

Figure 5-18 illustrates the turnaround scenario used for this analysis. Turnaround starts with the rendezvous and retrieval of the returning MOTV and Orbiter at LEO (block No. 3) and terminates with the MOTV final mission preps and transfer ignition from LEO to GEO (block No. 23). It includes the following major activities:

- Maintenance Preps - All MOTV activities required to remove it from the orbiter and prepare it for maintenance

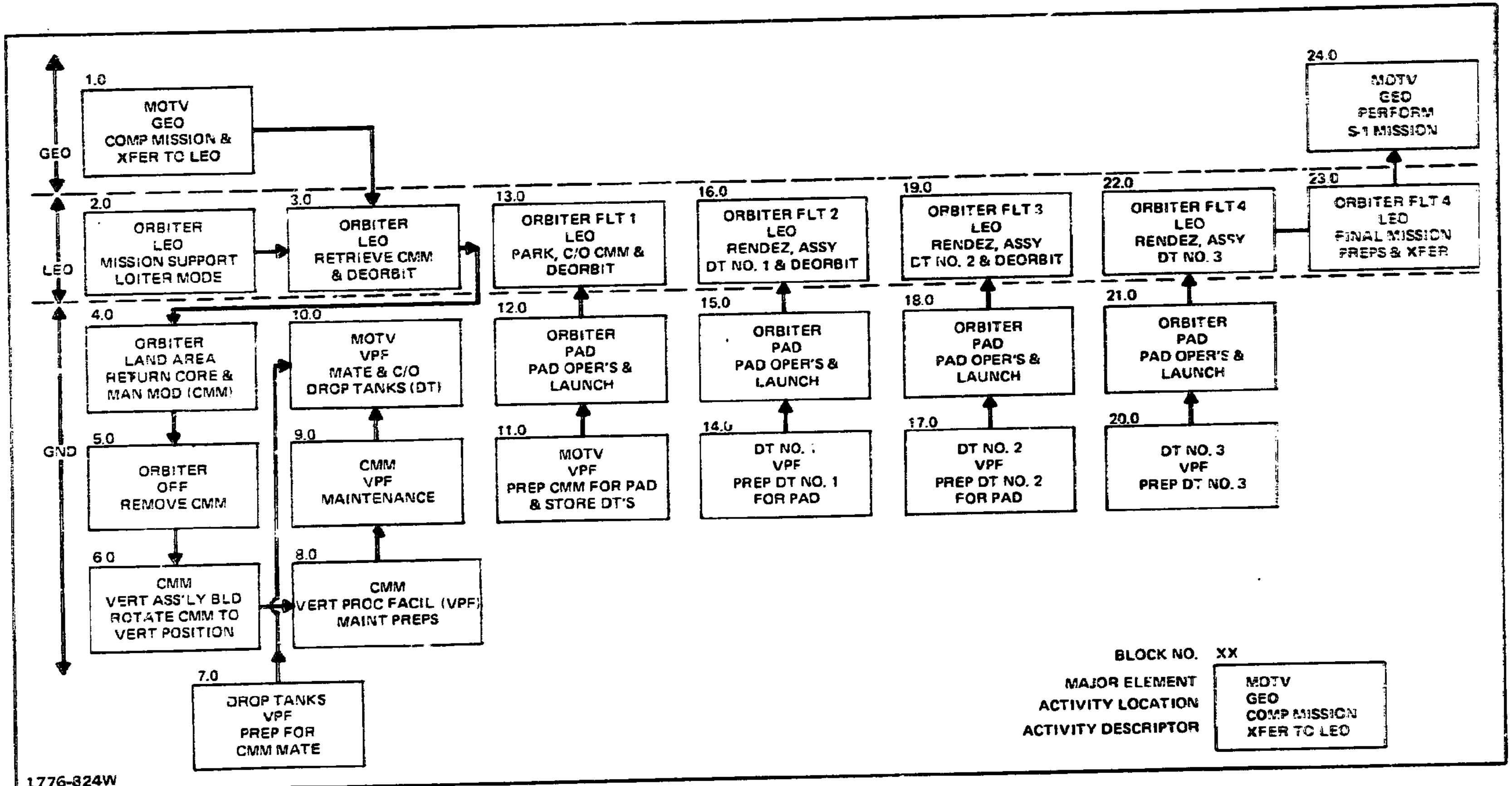


Fig. 5-18 MOTV S-1 Reference Mission Ground Turnaround Level 1 Flow

- Scheduled Maintenance - Tasks and actions preplanned to be accomplished at specified intervals in order to maintain the subsystem reliability levels; these functions include analysis of flight data, inspection, checkout (C/O), calibration, adjustments, replacements, and servicing
- Unscheduled Maintenance - Corrective action required to restore degraded equipment to its original level of reliability; this is not preplanned but is required as a result of crew reports, analysis of flight data and scheduled inspections, calibrations, or C/O
- Drop Tank Processing - Preparation of tank modules
- Core/Drop Tank Integration - Mate and C/O of complete MOTV mission configuration
- Pad Preps - Final cabin stowage and prep for move to pad
- Pad Operations - Integration with orbiter, fueling, and launch
- Assembly at LEO - Assembly of mission configuration, final checks, and orbit transfer ignition
- Final Mission Preps - Final storage of equipment and expendables, crew transfer.

There are generally three levels of maintenance. Our analysis will deal with Level I, which applies to all maintenance performed directly on installed hardware including required analysis to determine corrective action. Levels II and III, which deal with either on site or off site maintenance in support of Level I, were not addressed.

5.5.3 Functional Requirements/Schedule

Figure 5-19 details the various tasks required to meet the subsystem maintenance, handling, and ground turnaround requirements. They include a listing of the functional tasks and estimated times, plus general comments relative to software and GSE. Figure 5-20 illustrates the integration of Fig. 5-19 tasks into a Level I schedule. The schedule indicates MOTV off line tasks require a total of 98 serial hours which are well within the Shuttle schedule constraints for pad installation.

5.5.4 Manpower Requirements

Figure 5-21 lists the estimated manhours for each of the tasks. It is a duplicate of Fig. 5-19, with manhours instead of task durations listed for each task. Figure

TASK NO.	LOCATION	INTEG LEVEL	FUNCTIONAL REQM'T	TIME,HR	SOFTWARE	EQUIPT	REMARKS
1.0	LANDING AREA	I	NONE	–	–	–	FINAL MOTV C/O PRIOR TO LNDG. REMOVE FLT ORBITER EQUIP & TASK
2.0	ORBITER		INSTALL P/L ACCESS PLATFORMS CORE/MAN MODULE (CMM) PRELIM INSPECTION & PHOTOS	1	NONE	WK PLATFORMS	
2.1	PROCESSING		ATTACH HANDLING SLING & STRONG BACK	1.5		SLINGS & STRONGBACK	STRONG BACK STD ORBITER EQUIP
2.2	FACILITY						
2.3	OPF	II	INSTALL CMM IN HORIZONTAL CANNISTER	2.0			
2.4			INSTALL CANNISTER ON XPORTER	2.1			
2.5			XPORT TO VAB	4			
3.0	VAB		ROTATE CANNISTER TO VERTICAL POSITION	2			2 HIG BAY CRANES USED
3.1			XPORT TO VPF	4			
4.0	VPF		PLACE CANNISTER NEXT TO	1			VPF CRANE USED
4.1			REMOVE CMM FR CANNISTER	1			P/L REMOVAL EQUIP USED
			INSTALL IN INTEGRATED WORK STAND	1			VPF CRANE USED
4.2			POSITION WORK PLATFORMS			WK PLATFORMS	
4.3			POST FLT DAMAGE INSPECTION & PHOTOGRAPHY	2			
4.4			POSITION & MATE GSE	2		FLUID & ELECT GSE PLUS	
4.5			ESTABLISH CABIN CONDITIONING	1			
4.6			REMOVE ACCESS DOORS	2		LPS C/O	
CMM READY FOR SCHEDULED/UNSCHEDULED MAINTENANCE						INTERFACE UNITS	
5.0	VPF		SCHEDULED MAINTENANCE				
5.1	INTEGRATED WORK STAND		VISUAL INSPECTIONS: STRUCT/TANK SUPPORTS; DOCKING MECH; AVIONICS COMPONENTS & CNTR'LS SOLAR ARRAY & EPS; RR, COMM & TELEMETRY ANTENNAS; MAIN ENGINE NOZZLE & TURBINE COMPONENTS: FLUID LINES; ECLSS PLUMBING & COMPONENTS; ALL ORBITER P/L BAY INTERFACES; RADIATION PROTECTION TILES; PROTECTIVE COVERS; SELECTED STRUCT/MECH COMPONENTS FOR EVIDENCE OF PHYSICAL WEAR; RADIATOR PANELS; FLT CNTRL THRUSTERS	10			

1776-825W (1/2)

Fig. 5-19 Core Manned Module Turnaround Functional Requirements (Sheet 1 of 3)

TASK NO.	LOCATION	INTEG LEVEL	FUNCTIONAL REQM'T	TIME,HR	SOFTWARE	EQUIPT	REMARKS
5.2			REMOVAL & REPLACEMENT OF TIME LIMIT & EXPENDABLES FUEL, & H_2O FILTERS; SELECTED RCS, ENGINE & FUEL CELL COMPONENTS; SOLAR ARRAY & BATTERIES; IMU, SENSORS & POTS REQUIRING BENCH CALIBRATION	12			
5.3			END TO END LEAK CHECKS, RELIEF VALVE & REDUNDANT VALVE CHECKS OF PROP, ATTITUDE CNTRL, ECLSS, EPS	8	CNTRL & C/O ROUTINES		TO BE ACCOMPLISHED FLOWING SCHED & UNSCHEDULED COMPONENT REPLACEMENT
5.4	VPF INTEGRATED STAND	II	COMPLETE FUNCTIONAL END TO END POST MAINTENANCE C/O: EPS PWR UP, COMPUTER SELF CHECK, CONTROLS & DISPLAYS, PWR SWITCH OVER ECLSS FUNCTIONALS, COMM & INTER COMM FUNCT., IMU SELF & POLARITY TESTS, HORIZON & STAR SENSOR FUNCTIONAL, RR FUNCTIONAL LOAD & CHECK MISSION SOFTWARE & MISSION SIM INCLUDING MAIN ENGINE GIMBALING & RCS SIM. FIRING	10	C/O & CONTROL SOFTWARE	FLUID ELECTRICAL GSE INCLUDING ANTENNA HATS	WITH LPS & GROUND COMPUTER CONDUCTED AT END OF SCHED & UNSCHEDULED MAINTENANCE
6.0	UNSCHEDULED MAINTENANCE TYPICAL ITEMS						TOTAL OF 48 HR ALLOTED FOR UNSCHEDULED MAINTENANCE
6.1	VPF INTEGRATED STAND	II	NON DESTRUCTIVE TESTS & REPAIR OF STRUCTURE, TANKS, TILES, THERMAL BLANKETS, MECH COMPONENTS	24			
1776-625W (2/2)							

Fig. 5-19 Core Manned Module Turnaround Functional Requirements (Sheet 2 of 3)

TASK NO.	LOCATION	INTEG LEVEL	FUNCTIONAL REQM'T	TIME, HR	SOFTWARE	EQUIP.	REMARKS
6.2			DIAGNOSTIC TESTING TO VERIFY & ISOLATE ANOMALIES	8			
6.3			REMOVE & REPLACE LRV'S SECONDARY STRUCTURE OR FLUID LINES	8			
6.4			FURTHER INSPECTION OF SUSPECT AREAS REQUIRING PARTIAL DISASSEMBLY OF EQUIPMENT OR STRUCTURE	8			
6.5			REMOVAL & REPLACEMENT OF MAJOR ASSEMBLY FOR OVERHAUL	8			
6.6			PREP FOR MATE WITH TANKS	1			
7.0	DROP TANK MODULES PROCESSING						
7.1	LNDG AREA	II	UNLOAD TANK MODULE CANNISTER FOR A/C TO XPORT DOLLY	4		XPORT DOLLY	KSC AIRSTRIP
7.2	VPF		XPORT TO VPF	4			
7.3			ROTATE CANNISTER TO VERTICAL POSITION	1			
7.4	INTEGRATED WORK STAND		INSTALL IN INTEGRATED WORK STAND	1		VPF CRANE	
7.5			POSITION WORK PLATFORMS	0.5			
7.6			REMOVE ACCESS COVERS	1			
7.7			INCOMING INSPECTION	3			
7.8			PREPARE TO MATE WITH CORE MODULE	1			
8.0	CORE/CREW AND DROP TANK MODULE INTEGRATION						
8.1	INTEGRATED STAND		MATE CMM & DROP TANKS & VISUAL CHK OF INTERFACE	1			
8.2			VERIFY COMMAND LINE	0.25			
8.3			DEMATE	0.5			
8.4			REPLACE DROP TANK PANELS	1.5			FOLLOWING INTEGRATED TEST MODULES EITHER SHIPPED TO PAD OR STORAGE
8.5			REMOVE WK PLATFORMS	0.5			
8.6			PREPARE FOR STORAGE	1			
8.7	INTEGRATED	II	CLEAN CABIN & CORE EXTERIOR	6			
8.8	WORK		POWER DOWN & SECURE ALL SYSTEMS	2			
8.9	STAND		LOAD MISSION KITS & CLOSE OUT CABIN	8			
8.10			DISCONNECT & REMOVE GSE	2			
8.11			REMOVE WORK PLATFORMS	1.5			
8.12			INSTALL IN C/O CELL	2			VPR CRANE
8.13			XFER TO VERT CANNISTER	1		CANISTER XPORTER	
8.14			INSTALL ON XPORTER	1			STO MULTI-MISSION TRANSPORTER
8.15			XPORT TO PAD	4			

1776-826W

Fig. 5-19 Core Manned Module Turnaround Functional Requirements (Sheet 3 of 3)

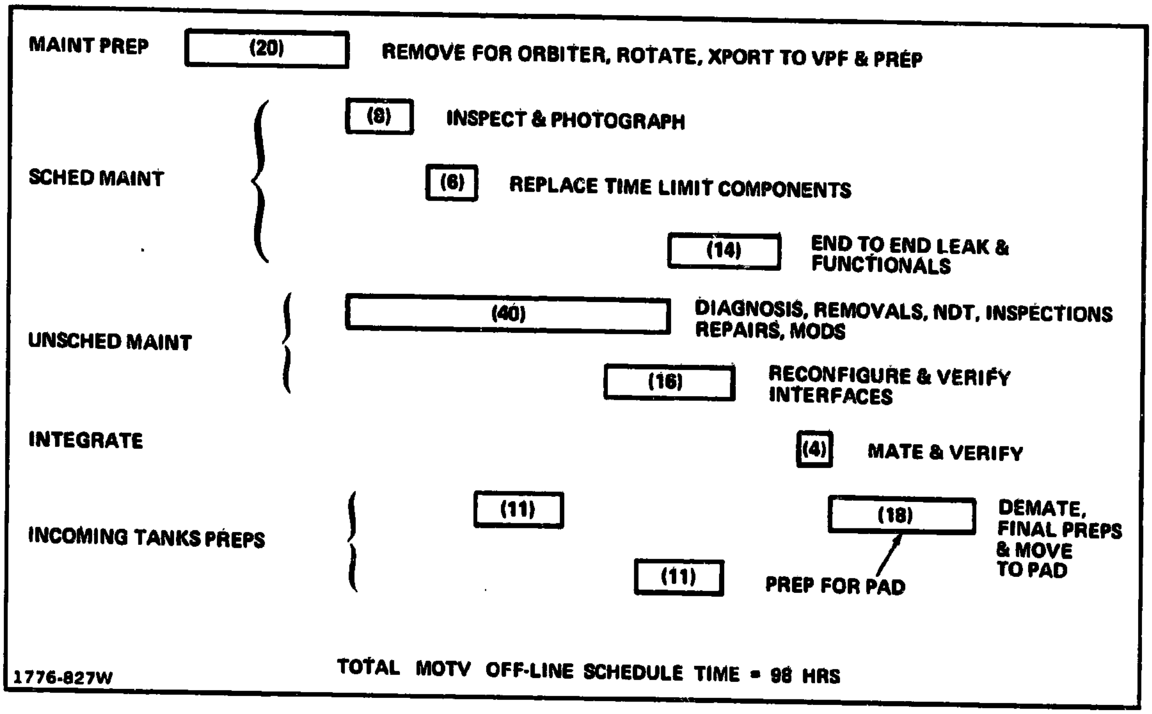


Fig. 5-20 Updated Ground Baseline Turnaround Schedule

TASK NO.	LOCATION	INTEG LEVEL	FUNCTIONAL REQM'T	MANHOURS	SOFTWARE	EQUIPT	REMARKS
1.0	LANDING AREA	I	NONE	–	–	–	FINAL MOTV C/O PRIOR TO LNDG-RE-MOVE FLT
2.0	ORBITER		INSTALL P/L ACCESS PLAT-FORMS	8	NONE	WK PLATFORMS	ORBITER EQUIP. & TASK
2.1	PROCESS-ING FACILITY		CORE/MAN MODULE (CMM) PRELIM. INSPECTION & PHOTOS	4			
2.2			ATTACH HAN-DLING SLING & STRONG BACK	3		SLINGS & STRONGBACK	STRONG BACK STD ORBITER EQUIP.
2.3	OPF	II	INSTALL CMM IN HORIZON-TAL CANNISTER	6			
2.4			INSTALL CANNISTER ON XPORTER	2			
2.5			EXPORT TO VAB	8			
3.0	VAB		ROTATE CANNISTER TO VERTICAL POSITION	10			2 HIG BAY CRANES USED
3.1			XPORT TO VPF	8			
4.0	VPF		PLACE CANNISTER NEXT TO	2			VPF CRANE USED
4.1			REMOVE CMM FR CAN-NISTER	4			P/L REMOVAL EQUIP. USED
			INSTALL IN INTEGRATED WORK STAND	4			VPF CRANE USED
4.2			POSITION WORK PLAT-FORMS			WK PLATFORMS	
4.3			POST FLT DAMAGE INSPEC-TION & PHOTOGRAPHY	10 16			
4.4			POSITION & MATE GSE	10		FLUID & ELECT	
4.5			ESTABLISH CABIN CON-DITIONING	2		GSE PLUS	
4.6			REMOVE ACCESS DOORS	12		LPS C/O	
CMM READY FOR SCHEDULED/UNSCHEDULED MAINTENANCE						INTERFACE UNITS	
5.0	VPF INTEGRATED WORK STAND		SCHEDULED MAINTENANCE				
5.1			VISUAL INSPECTIONS: STRUCT/TANK SUPPORTS; DOCKING MECH; AVIONICS COMPONENTS & CNTR'LS SOLAR ARRAY & EPS; RR, COMM & TELEMETRY AN-TENNAS; MAIN ENGINE NOZZLE & TURBINE COM-PONENTS: FLUID LINES; ECLSS PLUMBING & COM-PONENTS; ALL ORBITER P/L BAY INTERFACES; RA-DIATION PROTECTION TILES; PROTECTIVE COV-ERS; SELECTED STRUCT/ MECH COMPONENTS FOR EVIDENCE OF PHYSICAL WEAR; RADIATOR PANELS FLT CNTRL THRUSTERS	120			
5.2			REMOVAL & REPLACE-MENT OF TIME LIMIT & EXPENDABLES: FUEL, & H_2O FILTERS; SELECTED RCS, ENGINE & FUEL CELL COMPO-NENTS; SOLAR ARRAY & BATTERIES; IMV, SEN-SORS & POTS REQUIRING BENCH CALIBRATION	160			
1776-828W (1/3)							

Fig. 5-21 Core Manned Module Ground Turnaround Functional Requirements (Sheet 1 of 3)

TASK NO.	LOCATION	INTEG LEVEL	FUNCTIONAL REQM'T	MANHOURS	SOFTWARE	EQUIPT	REMARKS
5.3			END TO END LEAK CHECKS, RELIEF VALVE & REDUNDANT VALVE CHECKS OF PROP, ATTITUDE CNTRL, ECLSS, EPS	140	CNTRL & C/O ROUTINES		TO BE ACCOMPLISHED FLOWING SCHED & UNSCHEDULED COMPONENT REPLACEMENT
5.4	VPF INTEGRATED STAND	II	COMPLETE FUNCTIONAL & END TO END POST MAINTENANCE C/O: EPS PWR UP, COMPUTER SELF CHECK, CONTROLS & DISPLAYS, PWR SWITCH OVER ECLSS FUNCTIONALS, COMM & INTER COMM FUNCT., IMU SELF & POLARITY TESTS, HORIZON & STAR SENSOR FUNCTIONAL, RR FUNCTIONAL LOAD & CHECK MISSION SOFTWARE & MISSION SIM INCLUDING MAIN ENGINE GIMBALING & RCS SIMULATED FIRING	100	C/O & CONTROL SOFTWARE	FLUID ELECTRICAL GSE INCLUDING ANTENNA HATS	WITH LPS & GROUND COMPUTER CONDUCTED AT END OF SCHED & UNSCHEDULED MAINTENANCE
6.0	UNSCHEDULED MAINTENANCE TYPICAL ITEMS						TOTAL OF 48 HR ALLOTTED FOR UNSCHEDULED MAINTENANCE
6.1	VPF INTEGRATED STAND	II	NON DESTRUCTIVE TESTS & REPAIR OF STRUCTURE, TANKS, TILES, THERMAL BLANKETS, MECH COMPONENTS	580			
6.2			DIAGNOSTIC TESTING & ASSOCIATED DATA ANALYSIS	410			
6.3			REMOVE & REPLACE LRU'S SECONDARY STRUCTURE OR FLUID LINES	420			
6.4			FURTHER INSPECTION OF SUSPECT AREAS REQUIRING PARTIAL DISASSEMBLY OF EQUIPMENT OR STRUCTURE	480			
6.5			MAJOR ASSEMBLY REPLACMENT OR SYSTEM MODIFICATION	450			
6.6			PREP FOR MATE WITH TANKS	6			
7.0	DROP TANK MODULES PROCESSING						
7.1	LNDG AREA	II	UNLOAD TANK MODULE CANNISTER FROM A/C TO XPORT DOLLY	16		XPORT DOLLY	KSC AIRSTRIP
7.2	VPF		XPORT TO VPF	8			
7.3			ROTATE CANNISTER TO VERTICAL POSITION	2			
7.4	INTEGRATED WORK STAND		INSTALL IN INTEGRATED WORK STAND	4		VPF CRANE	
7.5			POSITION WORK PLATFORMS	2			
7.6			REMOVE ACCESS COVERS	4			
7.7			INCOMING INSPECTION	24			
7.8			PREPARE TO MATE WITH CORE MODULE	4			

1776-828W (2/3)

Fig. 5-21 Core Manned Module Ground Turnaround Functional Requirements (Sheet 2 of 3)

TASK NO.	LOCATION	INTEG LEVEL	FUNCTIONAL REQM'T	MANHOURS	SOFTWARE	EQUIPT	REMARKS
8.0	CORE/CREW AND DROP TANK MODULE INTEGRATION						
8.1	INTEGRATED STAND		MATE CMM & DROP TANKS & VISUAL CHK OF INTER-FACE	4			
8.2			VERIFY COMMAND LINE	6			
8.3			DEMATE	4			
8.4			REPLACE DROP TANK PANELS	3			FOLLOWING INTEGRATED TEST MODULES EITHER SHIPPED TO PAD OR STORAGE
8.5			REMOVE WK PLATFORMS	2			
8.6			PREPARE FOR STORAGE	4			
8.7	INTEGRATED	II	CLEAN CABIN & CORE EX-TERIOR	24			
8.8	WORK		POWER DOWN & SECURE ALL SYSTEMS	8			
8.9	STAND		LOAD MISSION KITS & CLOSE OUT CABIN	32			
8.10			DISCONNECT & REMOVE GSE	8			
8.11			REMOVE WORK PLATFORMS	6			
8.12			INSTALL IN C/O CELL	4			
8.13			XFER TO VERT CANNISTER	4		CANNISTER	VPR CRANE
8.14			INSTALL ON XPORTER	2		XPORTER	
8.15			XPORT TO PAD	8			STO MULTI-MISSION TRANS-PORTER
9.0	FINAL PAD OPERATIONS						
9.1	PAD	I	P/L INTEGRATION	7.5			P/L HANDLING MECHANISM
9.2		I	REFUEL CORE	4.0			
1776-829W (3/3)							

Fig. 5-21 Core Manned Module Ground Turnaround Functional Requirements (Sheet 3 of 3)

5-22 lists the peak manpower requirements for each of the major turnaround operations. It includes the quantity and skill of the manpower directly involved with the various turnaround operations.

5.5.5 Facility Mods and Ground Support Equipment (GSE) Requirements

Figure 5-18 is a layout of the integrated work stand in the KSC Vertical Processing Facility (VPF). This portable stand will accommodate all MOTV ground tasks, including final maintenance preps, maintenance, integration of the core with the drop tanks, and final preps prior to moving to the pad. Standard facility power will have to be supplied to the work stand. The two standard VPF work stands will be used for any MOTV contingency over flow tasks which might be required when the Integrated Work Stand is being used. Each standard cell will accommodate the Core and/or Crew Module and each of the drop tanks.

5.5.5.1 Mechanical GSE. Twenty pieces of mechanical GSE have been identified during this study, having a total value of approximately $920,000. The mechanical GSE consists of slings to handle the major modules and subsystems, portable work stands, an integrated MOTV work stand, and various other items of mechanical equipment to support buildings, handling, and checkout of the MOTV system, see Figs. 5-17 and 5-23.

5.5.5.2 Transportation GSE. Thirteen pieces of transportation equipment have been identified, having a total value of $1,150,000. This equipment will be used to transport the Core Modules and Drop Tanks from the factory to test sites and to KSC. They consist of Transporters, Environmental Covers, Shipping Containers, Environmental Control Units, and Tiedown devices, see Fig. 5-24.

5.5.5.3 Fluid GSE. Twenty-two pieces of Fluid GSE have been identified in this study with a total value of $1,995,000. This equipment will be used to check out and service the various fluid subsystems of the MOTV such as the ECLSS, Propulsion System, RCS, Waste Management, and Fuel Cells at the factory, test sites, and launch sites. Fluids serviced include Gaseous and Liquid Oxygen, Liquid Hydrogen, Nitrogen, Helium, Hypergolic Propellants, Water, and Air, see Fig. 5-25.

5.5.5.4 Avionics. Fifteen units have been identified during this study, having a total value of approximately $1,150,000. These units will be used to test and maintain the various avionics suosystems during electronic integration and checkout of the MOTV, see Fig. 5-26.

5.5.5.5 Power. Six units have been identified during this study, having a total value of approximately $350,000. These units will be used to maintain, charge, and provide

ACTIVITY AREA	MAINT PREPS	MAINTENANCE	INTEGRATE	PREP FOR MOVE
INSIDE CABIN	(2) 1 TECH, 1 ENG.	(2) TECH, 1 ENG.	(1) ENG.	(2) TECHS
OUTSIDE CABIN	(2) TECHS	(2) TECHS		(2) TECHS
AROUND INTERSTAGE	(1) TECH	(2) TECHS		(1) TECH
AROUND CORE	(2) TECHS	(2) TECHS		(2) TECHS
LPS (CONSOLE)		(2) SYS ENG.		
MAINT ANALYSIS CNTR		(4) SUBSYSTEM SPECIALIST		
GSE	(2) TECHS	(2) TECHS		(2) TECHS
DROP TANKS			(2) TECHS	
QC	(1)	(2)	(1)	(1)
MAINT DIRECTOR		(1)		
CRANE OPERATOR			(1)	
PHOTOGRAPHER		(1)		
PEAK MANPOWER TOTALS	10	20	4	10
1776-830W				

Fig. 5-22 Peak Manpower Utilization for Ground Turnaround Activities

1)	CREW COMPARTMENT SLING	$50,000
2)	DROP TANK/CORE MODULE SLING SET	50,000
3)	DROP TANK SUPPORT RINGS (2)	80,000
4)	PORTABLE WORKSTANDS – DROP TANK/CORE (3)	90,000
5)	ENGINE DOLLY (2)	100,000
6)	ENGINE SLING	30,000
7)	MODULE INSTALLATION FIXTURES (4)	120,000
8)	INTEGRATED ASSEMBLY WORKSTAND	200,000
9)	CORE MODULE SUPPORT RING	40,000
10)	ENGINE THROAT PLUGS (2)	40,000
11)	PYRO SIMULATOR SET (1)	30,000
12)	SOLAR ARRAY DEPLOYMENT FIXTURE	90,000
	TOTAL 20 PIECES	$920,000

TOTAL $4,065,000

1776-831W

Fig. 5-23 Mechanical GSE – MOTV

1)	DROP TANK TRANSPORTERS (2)	$400,000
2)	DROP TANK ENVIRONMENTAL COVERS (2)	40,000
3)	DROP TANK SHIPPING CONTAINERS (2)	120,000
4)	TRANSPORTATION TIEDOWN SET	80,000
5)	TRANSPORTER COOLING & PRESS. UNIT (3)	120,000
6)	CORE MODULE TRANSPORTER	250,000
7)	CORE MODULE ENVIRONMENTAL COVER	30,000
8)	CORE MODULE SHIPPING CONTAINER	80,000
	TOTAL 13 PIECES	$1,150,000

1776-832W

Fig. 5-24 Transportation GSE – MOTV

1)	CABIN AIR SUPPLY UNIT (800 + 800 = 1600 x 35)	$60,000
2)	GROUND COOLING UNIT	90,000
3)	CABIN LEAK TEST UNIT	50,000
4)	ECLSS CHECKOUT CART (1100 + 1000)	100,000
5)	GOX SERVICE UNIT	75,000
6)	GN_2 SERVICE UNIT	50,000
7)	LH_2 SERVICE UNIT	200,000
8)	LO_2 SERVICE UNIT	200,000
9)	CRYO SYSTEMS C/O UNIT	150,000
10)	WATER STORAGE & TRANSFER UNIT	90,000
11)	GOX SYSTEM VACUUM PUMP	40,000
12)	WATER SYSTEM VACUUM PUMP	40,000
13)	LEAK DETECTOR CART	20,000
14)	PROPULSION SYSTEM C/O UNIT	100,000
15)	HYPERGOLIC SERVICING UNIT – (1) FUEL	125,000
	– (2) OXIDIZER	125,000
16)	HELIUM PRESSURIZATION UNIT	70,000
17)	PURGE & DRYING CART	60,000
18)	FUEL CELL VACUUM PUMP	40,000
19)	FUEL CELL SERVICING UNIT	150,000
20)	WASTE MGMT SYST SERVICING UNIT	60,000
21)	Q.D./FILTER SET	100,000
	TOTAL 22 PIECES	$1,995,000

1776-833W

Fig. 5-25 Fluid GSE – MOTV

AVIONICS

1) CAUTION & WARNING ELECTRONIC ASSEMBLY STIMULI GENERATOR
2) RENDEZVOUS RADAR TEST BENCH
3) ATTITUDE CONTROL & DETERMINATION TEST STATION
4) COMMUNICATION CHECKOUT & MAINTENANCE TEST STATION
5) AUDIO CENTER DEVELOPMENT TEST STATION
6) DISPLAY AND CONTROL CONSOLE
7) PULSE CODE MODULATION & TIMING EQUIPMENT
8) INSTRUMENTATION STIMULI GENERATOR
9) S/C STATUS ACQUISITION SYSTEM
10) TV SYSTEM TEST SET
11) S-BAND UPLINK AND DOWNLINK TEST SET
12) S-BAND, X-BAND, KU BAND ANTENNA MAINT TEST STATION
13) DISPLAYS & CONTROL MAINTENANCE TEST STATION
14) PRN RANGING TEST SET
15) X-BAND DOWNLINK DATA TEST SET

POWER

1) DC TRANSIENT VOLTAGE POWER SUPPLY
2) CONSTANT CURRENT BATTERY CHARGER
3) INVERTER SIMULATOR
4) ELECTRICAL LOAD SIMULATOR
5) VEHICLE GROUND POWER SUPPLY
6) BATTERY MAINTENANCE TEST STATION

PROPULSION, ECS, RCS

1) ENVIRONMENTAL CONTROL SYSTEM TEST STATION
2) REACTION CONTROL S/S CONTROL STATION
3) HELIUM PRESSURIZATION CONTROL UNIT
4) RCS PRESSURIZATION CONTROL STATION
5) RCS FIRING CONTROL STATION
6) MAIN PROPULSION ELECTRICAL TEST SET

1776-334W

Fig. 5-26 Electrical GSE

an electrical load for the batteries. Also, to support the factory assembly and check-out of the MOTV, a vehicle ground power supply is used with an inverter simulator, see Fig. 5-26.

5.5.5.6 Propulsion, ECS, RCS. Six units have been identified during this study, having a total value of approximately $300,000. These units will be used to check out and test the various electrical components which are a part of ECS, RCS, and Propulsion Subsystems, see Fig. 5-26.

The total expense for Electrical GSE equal $1.8 million.

5.6 SHUTTLE-TENDED LEO TURNAROUND

Figure 5-27 illustrates the approach used to develop the Shuttle-tended LEO turnaround, as compared with the approach for ground turnaround discussed in paragraph 5.5. The approach was essentially the same for both, relative to philosophy, automation, and accessibility. The prime difference was the restriction on major disassembly inherent in Shuttle-tended turnaround. Shuttle turnaround could not accommodate contingencies (unscheduled maintenance) requiring major disassembly of the core or crew modules because of the inherent restrictions on the special equipment, fixtures, and tools that would be brought up on the Shuttle support flights

5.6.1 Groundrules

The following groundrules for Shuttle-tended LEO turnaround are in addition to those listed in paragraph 5.5.1 for ground turnaround:

- LEO turnaround operation will be conducted on a single shift, seven-day a-week basis
- The Shuttle will provide any special test equipment, manipulators, special fixtures, power, fluids, reactants, and fuel, as well as general logistics support
- The Shuttle will accommodate a maximum crew of seven for MOTV turnaround
- No maintenance will be scheduled for the first day because of crew acclimation problems.

5.6.2 Shuttle-Tended LEO Turnaround Functional Scenario

Figure 5-28 illustrates a typical Shuttle-tended LEO turnaround scenario. The first Shuttle rendezvous with the MOTV berths it, transfers the crew, performs

	GND BASED TURNAROUND	SHUTTLE TENDED LEO TURNAROUND
PHILOSOPHY	CONDITION MONITORING + MINIMAL TIME LIMIT	SAME
AUTOMATION	AUTOMATIC GND EQUIP-MENT + MAXIMUM OFI FLT DATA PRIME SOURCE	SAME PLUS DIRECT RF GND LINK
ACCESSIBILITY	MAXIMUM EXTERNAL & INTERNAL	SAME PLUS LRU'S EASILY REMOVABLE
MAINTENANCE RESTRICTIONS	NONE	NO MAJOR DISASSEMBLY @ LEO

1776-835W

Fig. 5-27 Comparison of Ground-Based vs Shuttle-Tended Turnaround Approach

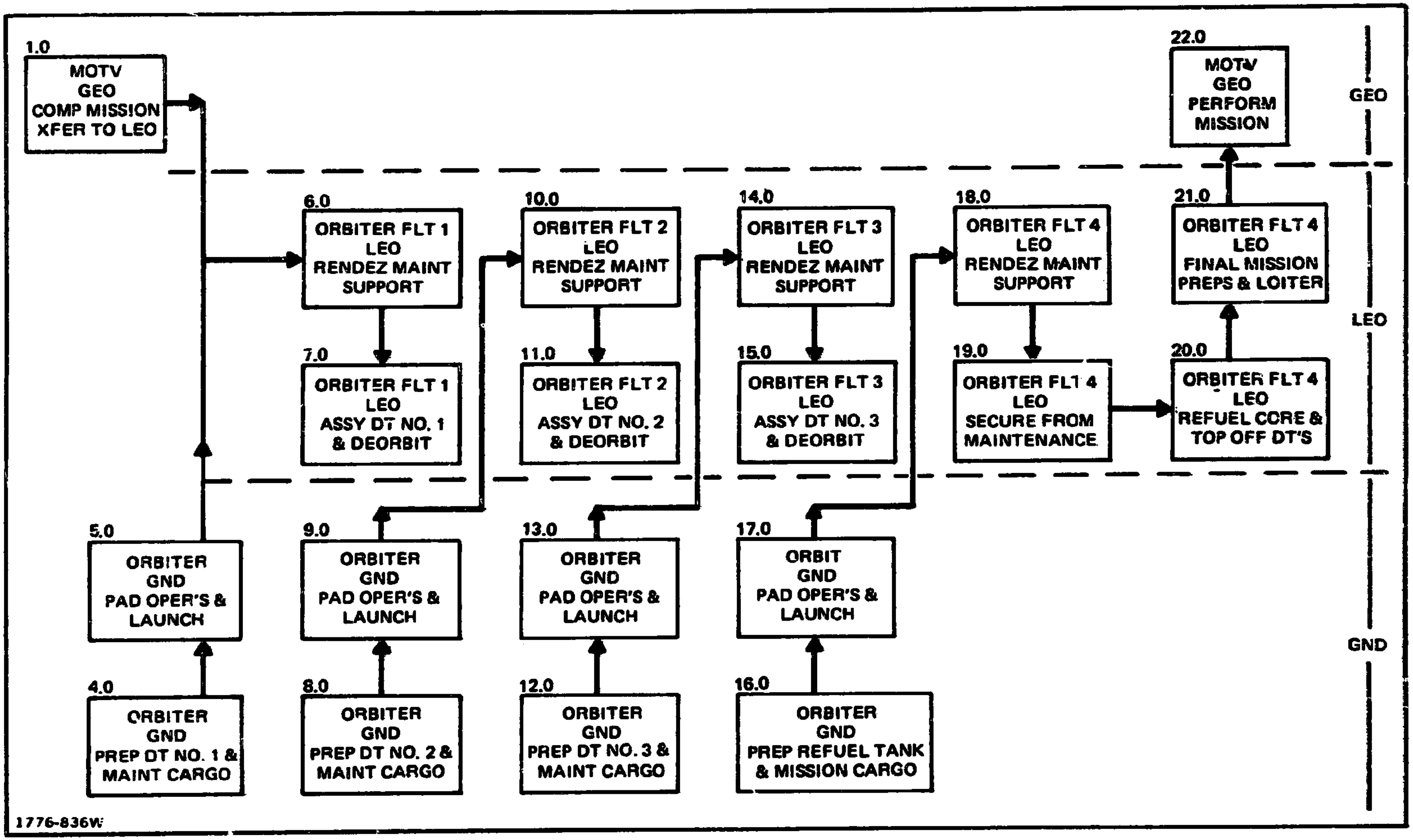


Fig. 5-28 MOTV S-1 Reference Mission LEO Turnaround Level I Functional Shuttle-Tended

scheduled maintenance tasks, assembles the drop tank it brought up, and parks and secures the MOTV. All turnaround activities will occur at LEO utilizing the Orbiter as the support base. The next two orbiters will bring up the remaining two drop tanks for the S-1 mission, plus the men, support equipment (diagnostic, handling, special tools, and fixtures), and spares required to complete the maintenance and tank assembly operations. The drop tank loading will be determined by mission and boil-off requirements (turnaround duration), plus the weight of the men and material required to support the maintenance operations. The fourth flight will therefore bring up fuel for the core and drop tank "top-off," if necessary. In addition, this fourth and last flight will bring up the remaining mission spares, expendables, and equipment required to support the next mission. The primary function of the last flight will be to secure from maintenance operations, transfer fuel, transfer the flight crew to the MOTV, and support mission preps.

5.6.3 Functional Requirements

Figure 5-29 details the functional requirements for the Shuttle-tended LEO turnaround. The scheduled and typical unscheduled maintenance activities listed are similar to those for ground operations and fulfill the subsystem requirements given in paragraph 5.3. Unlike the continuous sequence of tasks for ground operations, Fig. 5.19, Shuttle-tended activities are structured around the supporting Shuttle flights. The discontinuities in the maintenance operations inherent in the Fig. 5-29 arrangement will require a certain amount of duplication of effort. Figure 5-29 also includes preliminary estimates of times and manhours. These preliminary estimates are based on ground equivalent tasks and do not include adjustments for operation in the LEO environment. LEO equivalent times, manhours, and schedules are developed in Section 6.

5.6.4 Manpower Requirements

Figure 5-30 indicates the peak manpower requirements for each of the major Shuttle-tended turnaround activities. The maximum turnaround crew is assumed to be 7, since it is assumed that the turnaround will be conducted within the Shuttle schedule operational and safety constraints.

TASK NO.	LOCATION	FUNCTIONAL REQUIREMENTS	TASK TIME	MAN-HOURS	REMARKS
1.0	LEO	1ST SHUTTLE FLIGHT			
1.1		PREP FOR MAINTENANCE			
1.2		CAPTURE & BERTH RETURNING MODULE	2	4	
1.3		XFER CREWS & DEBRIEF	2	14	
		REMOVE ACCESS PANELS	3	12	
2.0		SCHEDULED & UNSCHEDULED MAINTENANCE			
2.1		DAMAGE & GENERAL INSPECTION: STRUCT AVIONICS, SOLAR ARRAY, ANTENNAS, MAIN ENGINE COMPONENTS, EXTERNAL SURFACES, RADIATOR PANELS, RCS & PLUMBING	10	70	MAINTENANCE ANALYSIS CONDUCTED BY GND SUPPORT CREW
2.2		PRELIMINARY DIAGNOSTIC TESTS TO VERIFY & ISOLATE ANOMALIES	14	162	
2.3		SCHEDULED REMOVALS & REPLACEMENT OF TIME LIMIT & EXPENDABLES PLUS LIMITED UNSCHEDULE LRU REPLACEMENT	10	90	SPECIAL TEST EQUIP. & SOFTWARE ABOARD STS
3.0		ASSEMBLY OF TANK			
3.1		MOVE TANK INTO POSITION	1	3	
3.2		MATE & VISUAL CHECKS OF INTERFACES	2	6	
3.3		SECURE & TRANSFER CREW	2	6	
3.4		DEPLOY, PARK & MONITOR	1	2	
		2ND SHUTTLE FLIGHT			
1.1		CAPTURE & BERTH PARKED MODULES	2	4	
2.0		CONTINUE UNSCHEDULED MAINTENANCE			
2.2		REMOVE & REPLACE LRU's	10	120	
2.3		LOCAL REPAIRS	24	288	
2.4		FLUID SYSTEMS LEAK CHECKS	6	36	
2.5		INITIATE CABIN STOWAGE & SERV. ECLSS	8	48	
3.0		ASSEMBLE 2ND TANK	6	20	
		3RD SHUTTLE FLIGHT			
1.1		CAPTURE & BERTH PARKED MODULES	2	4	
2.2		COMPLETE REMOVAL & REPLACEMENT	8	96	
2.3		COMPLETE MAINTENANCE	24	190	
2.4		CONDUCT FUNCTIONAL & END TO END TESTS	6	78	
2.5		COMPLETE CABIN STOWAGE & MISSION PREPS	8	24	
2.6		ASSEMBLE TANKS	6	18	
		4TH SHUTTLE FLIGHT			
1.1		FINAL CLOSEOUT INSPECTIONS	4	30	
1.2		SECURE FROM MAINT OPERATIONS	8	48	
1.3		SERVICE CORE PROPULSION & FUEL CELL TANKS	6	42	
1.4		PREP FOR MISSION	8	40	
1.5		TRANSFER CREW			
1.6		FINAL MISSION PREPS & CHECKS	3	20	
1.7		XFER IGNITION			

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Fig. 5-29 MOTV LEO Turnaround Shuttle-Tended Functional Requirements

ACTIVITY DESCRIPTOR	MAINT PREP	MAINTENANCE	ASSEMBLY & REFUEL	FINAL MISSION PREPS
ORBITER				
• RMS	1	1	1	
• TEST EQUIP/GSE		1	1	1
ON VEHICLE				
• INSIDE CABIN	1 SHIRT SLEEVE S/S	2 S/S	2 S/S	3
• OUTSIDE CABIN	1 EVA	1 EVA		1
• INTERSTAGE	1 OCP	1 OCP		1
• CORE	1 EVA	1 EVA	1 OCP	1
• DROP TANKS			1 EVA	
DIRECT GROUND SUPPORT				
• MAINT ANAL. CNTR	2 SUBSYS SPECIAL	5 SUBSYS SPECIAL	2 SUBSYS SPECIAL	2 SYSTEM SPECIAL
• MAINT DIRECTOR	1	1	1	
TOTALS:				
AT LEO	5	7	6	7
GROUND	3	6	3	2

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Fig. 5-30 Peak Manpower Utilization for STS-Tended LEO Turnaround

6 - LEO TURNAROUND UTILIZING THE SPACE OPERATIONS CENTER (SOC)

SOC, Fig. 6.1, is envisioned as a multipurpose facility for the development of the technology, the procedures, and the actual construction of large space systems which must be assembled in space and cannot be effectively developed within the orbiter mass, volume, or operational constraints. The Space Operations Center could also be used to turnaround the MOTV. The following paragraphs define the SOC requirements for MOTV turnaround.

6.1 SOC TURNAROUND GROUNDRULES

The following groundrules and assumptions governing the SOC analysis include:

- The 1½ stage All Propulsive MOTV Configuration for the S-1 mission, Fig. 5-4, is the configuration baseline
- Turnaround is from SOC at LEO and the orbital transportation vehicle is the standard STS
- MOTV turnaround will be conducted within with SOC operational and safety constraints
- Scheduled turnaround processing and maintenance operations will be conducted on a nominal eight-hour, single shift, seven-day-a-week basis with EVA and IVA operations as required
- The LEO depot team is responsible for the core/crew module turnaround activities, including routine maintenance, making on-the-spot observations, consulting with the ground maintenance control center on unscheduled maintenance tasks or abnormalities, and implementing the ground control corrective maintenance plans
- The SOC is assumed to be in a 265 kilometer circular, 28½° inclined orbit
- The ground maintenance depot is responsible for support of SOC, including real time scheduling and controlling maintenance activities, data reduction, determining maintenance corrective action, and logistics support

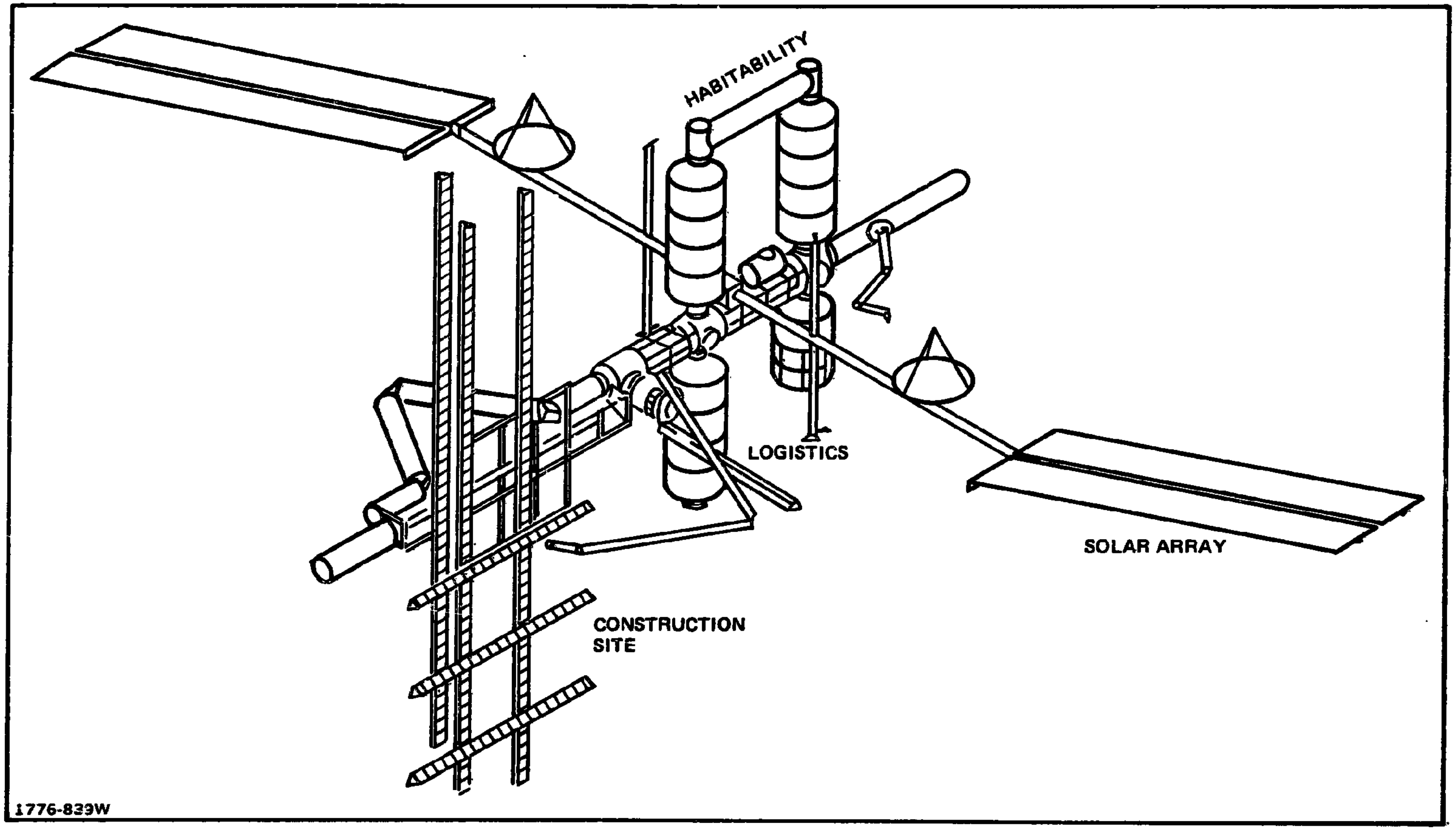

Fig. 6-1 Space Operations Center Configuration (SOC)

- Turnaround operations are defined as including all the activities between the orbit transfer ignition from GEO to LEO of the returning MOTV at the end of one GEO mission, to the orbit transfer burn from LEO to GEO, initiating the start of the next GEO mission
- MOTV crews are on 90-day rotation centers.

<u>LEO depot will have the following basic capability:</u>

- The baseline SOC depot configuration as shown in Fig. 6.1
- Power, spacecraft handling equipment, cranes, and IVA/EVA equipment to perform turnaround tasks
- Ground support equipment required for turnaround
- Voice, data, and command link with the ground maintenance control center
- Logistics capability for storing LRU's, test equipment, and tools
- Logistics capability for storing fuel tanks, other fluids, and required mission consumables.

<u>The S-1 MOTV configuration will have the following general characteristics:</u>

- Primary structure, exterior structural skin, and meteoroid bumpers are aluminum and are designed for on-orbit repair
- Accessibility is a prime design requirement and includes access doors, removable panels, and borescope-type ports to facilitate inspection and maintenance
- Maintainability is a prime design requirement and will include testability as well as LRU and/or major subassembly replaceability.

<u>The MOTV Avionics System will include the following features:</u>

- Orbital Flight Instrumentation (OFI) package which can monitor the health and status of all subsystems
- All avionics subsystems instrumented adequately to provide in-flight operational performance data
- Calibration and adjustment to be accomplished without component removal
- Data from checkout, fault isolation, status, and flight is transmitted to ground computer and is available for maintenance analysis.

The MOTV propulsion subsystem will include the following features:

- All main engine parallel redundant paths are "on line" and can be checked in flight
- Welding is the primary method for connecting fuel lines to each other and to valves; tanks are also weldment assemblies; inter-module connections are of the quick disconnect self-sealing type
- Leak detection tape or elastomeric paint is applied to all potential leakage connections except the QD's
- All main engine components except the thrust chambers and turbo pumps are line replaceable units (LRU)
- Provisions for internal inspection of the main engine thrust chamber and turbo pump components are available
- All components except thrust chambers, turbo pump, ignition system, and other limited-life items will have a time/life cycle good for a five-year life (approximately 15 missions).

The MOTV ECLSS subsystem will include the following features:

- All ECLSS redundant paths are "on line" and can be checked in flight
- Welding is the primary method for connection of fluid lines except for limited-life items which will incorporate quick disconnects
- All components, except motors, pumps, heaters, and other limited-life items will have a time/life cycle good for a five-year life (approximately 15 missions).

6.2 SOC TURNAROUND REQUIREMENTS

SOC turnaround requirements include maintenance preps, scheduled and unscheduled maintenance, assembly of the three tanks, refueling of the core, securing from maintenance operations, and final mission preps including final pre-ignition checks. Unlike Shuttle-tended, SOC turnaround is fairly well decoupled from the Shuttle resupply flights. The SOC logistics module contains the necessary MOTV spares, mission equipment and supplies. Per the groundrule stated previously ("MOTV crews are on 90-day rotation centers"), the MOTV turnaround crew is assumed to be in place aboard SOC prior to rendezvous of the MOTV with SOC. Turnaround activities can therefore be accomplished in a continuous and effective manner and are not constrained by Shuttle turnaround schedules. The Shuttle can deliver drop tanks,

resupply logistics, and provide core module fuel on a fairly flexible schedule consistent with MOTV flight rates and SOC MOTV hardware inventory levels. The only Shuttle flight that is coupled to the MOTV SOC turnaround schedule is the core refueling because of the refueling sequence which is discussed later. Figure 6-2 illustrates the overall scenario for SOC operations with Shuttle resupply taking place on a regular periodic schedule throughout the MOTV mission and turnaround activities.

Figure 6-3 lists the SOC functional turnaround requirements, along with preliminary time and manpower estimates based on performing equivalent tasks in the ground environment. Figure 6-3 illustrates that like ground and Shuttle-tended turnaround, maintenance, especially unscheduled maintenance, is the prime driver in terms of time, men, material, and manhours expended. In order to reduce maintenance tasks and thereby develop a viable SOC maintenance plan, it is necessary to implement:

- Maintainability changes in the MOTV subsystem
- Design of special tools and fixtures to facilitate maintenance tasks
- Changes to turnaround philosophy to further reduce maintenance activity.

6.2.1 SOC Maintenance Analysis

The MOTV subsystems and the functional requirements listed in Para. 5.3 were

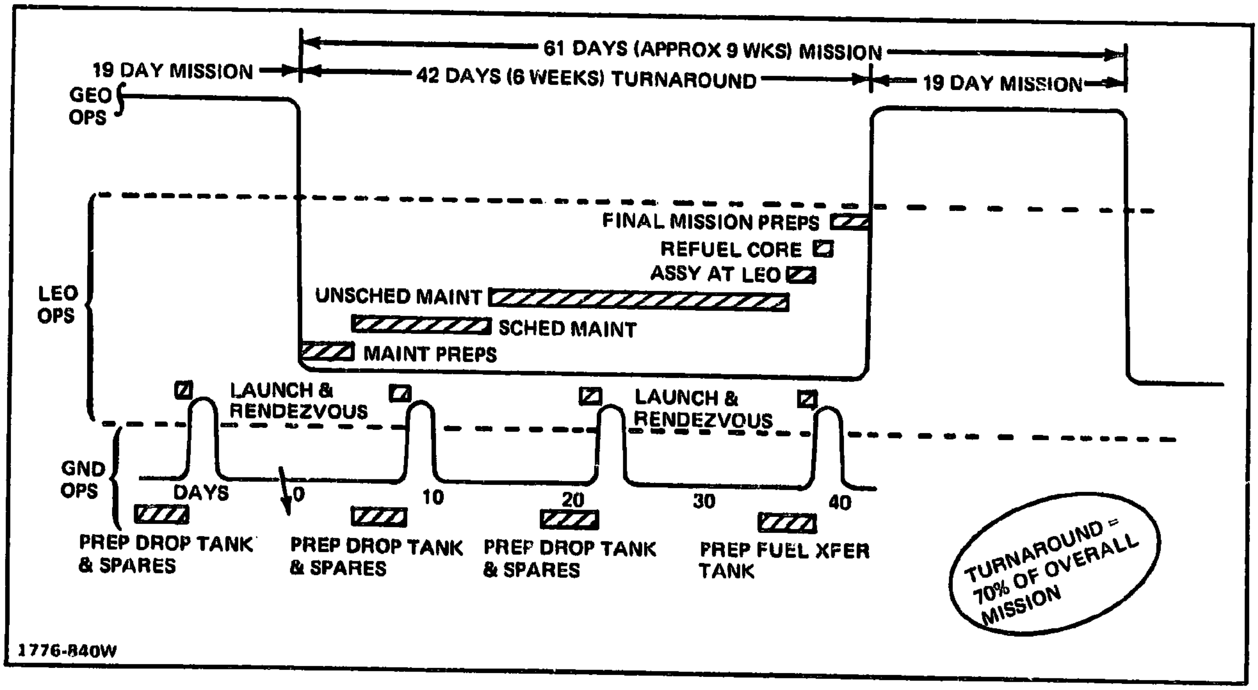

Fig. 6-2 LEO SOC Turnaround Scenario

TASK NO.	LOCATION	FUNCTIONAL REQUIREMENTS	TASK TIME	MAN-HOURS	REMARKS
1.0	LEO	MAINT PREPS: CAPTURE, BERTH, SECURE, DEBRIEF PREP OCP, REMOVE ACCESS PANELS & HOOK-UP PWR & SOC SUPT EQUIP (SSE)	8		
2.0		SCHEDULED MAINTENANCE			
2.1		DAMAGE & GENERAL INSPECTION: STRUCT, AVIONICS SOLAR ARRAY, ANTENNAS, MAIN ENGINE COMPONENTS, EXTERNAL SURFACES, RADIATOR PANELS, PLUMBING, ETC.	10	90	
2.2		SCHEDULED REPLACEMENT OF TIME LIMITED LRU'S & COMPONENTS	10	90	
2.3		CALIBRATE 1/5 OF XDUCERS EACH FLT	4	20	
2.4		OVERALL LEAK CHECKS OF FLUID SYS & FUNCTIONALS FOR ALL SUBSYSTEMS INCLUDING LOADING MISSION SOFTWARE & CONDUCTING FULL UP MISSION READINESS TESTS	10	150	CONDUCTED POST MAINT SCHED & UNSCHED
2.5		SERVICE ECLSS, EPS, FLUID & MECH SUBSYSTEMS	8	30	
3.0		UNSCHEDULED MAINTENANCE			
3.1		REPAIR STRUCT, THERM BLKTS, TILES, SOLAR ARRAY, ETC.: NON-DESTRUCT TESTS FOR CRACKS, DEBOND, ETC.: MISSION PECULIAR OR GENERAL IMPROVE MODS	24	288	
3.2		DIAGNOSTIC TEST TO ISOLATE ANOMALIES INCLUDING FLUID LEAK CHECKS & FUNCTIONALS INCLUDING INDIVID COMPONENT THROUGH INTEGRATED SUBSYSTEM TEST USING TEST ROUTINES	12	180	
3.3		UNSCHED REPLACEMENT OF LRU'S INCLUDING NECESSARY PREPS	10	120	
3.4		FURTHER INSPECTION OF SUSPECT AREAS REQUIRING FURTHER DISASSY	8	40	
3.5		POST MAINT RECONFIGURE			
4.0		ASSEMBLY 3 DROP TANKS	12	84	
5.0		REFUEL CORE MODULE	6.5	46	
6.0		FINAL STOWAGE OF CREW CABIN & MISSION PECULIAR HDW	8	56	
7.0		CLOSEOUT INSPECTION OF ALL OPEN AREAS	4	28	
8.0		REPLACE PANEL, REMOVE GSE & SECURE	4	20	
9.0		XFER CREW & FINAL MISSION PREPS & OVERALL CHECKS	3	20	

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Fig. 6-3 MOTV LEO Turnaround SOC

revisited to determine what changes could be made to facilitate or reduce SOC maintenance.

In addition to improving the hardware reliability which would reduce unscheduled repair and replacement, the following requirements should be considered:

MOTV design requirements

- Loose hardware (normally required for mounting) will be captured or tethered
- LRU's will be reasonably sized for handling, selected at higher assembly levels and should be standardized whenever possible in order to reduce the number of LRU's and special tool requirements. LRU's should be selected at a level which minimizes the number of interfaces that have to be broken and revalidated. LRU mechanical fasteners will be of the quick make release type (latch or quarter turn) whenever possible
- Alignment pins should be added to LRU assemblies in order to reduce alignment problems and possible damage during replacement
- Fluid subsystem disconnects should be of the self-sealing, zero entrapment type whenever possible. Figure 6-5 is a preliminary estimate of the LRU's for the various subsystems based on the above maintainability requirements

Special tools

Figure 6-4 illustrates some of the special tools developed which might be modified for MOTV application

Turnaround philosophy

Limiting unscheduled maintenance to remove and replace operations as much as possible should reduce the amount of special tools, technical specialists, and material inventory, as well as reduce the overall maintenance manpower.

Implementing these re uirements will minimize the costs of an effective SOC turnaround program.

6.2.2 SOC Manpower Requirements

Figure 6-3, located on the opposite page, contains a preliminary estimate of task times and manhours based on performing equivalent functional requirements on the ground. These are all right for a first approximation but do not provide a reasonable estimate of the SOC LEO manpower requirements because they do not reflect

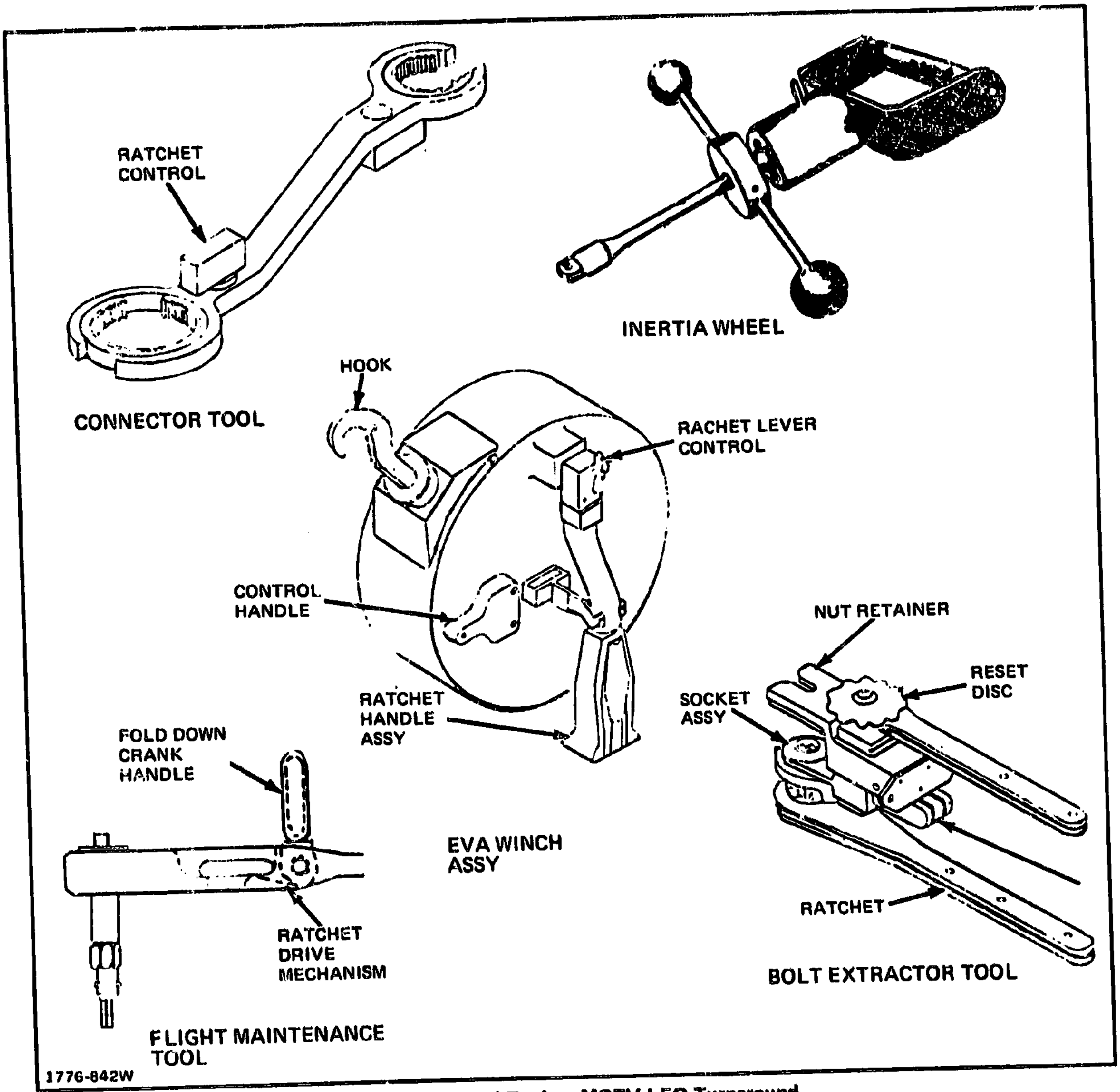

Fig. 6-4 Special Tools – MOTV LEO Turnaround

1.0	**MAIN ENGINE**
1.1	ENGINE ASSEMBLY
1.2	FUEL INLET SHUT-OFF VALVE
1.3	OXIDIZER INLET SHUT-OFF VALVE
1.4	SOLENOID VALVES
1.5	FUEL TANK PRES. VALVE
1.6	OXIDIZER TANK PRESS. VALVE
1.7	GOX HEAT EXCHANGER
1.8	CONTROL ACTUATORS
1.9	TEMPERATURE SENSORS
1.10	SPEED TRANSDUCER
1.11	IGNITER TORCH
1.12	IGNITION SYSTEM
1.13	PRESSURE SWITCHES
1.14	NOZZLE COOLANT VALVE
1.15	MAIN FUEL SHUT-OFF VALVE
2.0	**PROPELLANT SYSTEM**
2.1	FUEL RELIEF VALVE MODULE
2.2	OXIDIZER RELIEF VALVE MODULE
2.3	HELIUM REGULATOR MODULE
2.4	HELIUM QUAD CHECK VALVE MODULE
2.5	FUEL SHUT-OFF VALVE
2.6	OXIDIZER SHUT-OFF VALVE
2.7	FUEL FILTER
2.8	OXIDIZER FILTER
2.9	PRESSURE TRANSDUCERS
3.0	**RCS**
3.1	RCS ENGINE ASSEMBLY
3.2	HELIUM VALVE MODULE
3.3	HELIUM REGULATOR MODULE
3.4	RELIEF VALVE ASSEMBLY
3.5	FUEL VALVE ASSEMBLY
3.6	FUEL FILTER
3.7	PRESSURE TRANSDUCERS

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Fig. 6-5 Candidate LRU's for MOTV In-Orbit Replacement at SOC

the ability to work in the LEO environment. Figure 6-6 summarizes the steps used to calculate LEO manpower data, along with the results. The logic used is as follows:

1) Figure 5-21, which tabulates ground manhours for similar tasks, and Fig. 5-22, which tabulates the number of "hands on" vehicle people and direct support personnel, were used as the baseline

2) The direct "hands on" manhours were calculated by multiplying ground manhours for each task, Fig. 5-21, by the ratio of vehicle people to the total for

4.0 ECLS
4.1 CABIN HEAT EXCHANGER/FAN ASSEMBLY
4.2 AVIONICS COOLING ASSEMBLY
4.3 CO_2 REMOVAL ASSEMBLY
4.4 O_2 GENERATION ASSEMBLY
4.5 WATER RECLAMATION ASSEMBLY
4.6 WASTE MANAGEMENT ASSEMBLY
4.7 PRIMARY PUMP ASSEMBLY
4.8 SECONDARY PUMP ASSEMBLY
4.9 POTABLE WATER TANK ASSEMBLY
4.10 O_2/N_2 CONTROL ASSEMBLY
4.11 N_2 TANK ASSEMBLY 1776-844W

Fig. 6-5 Candidate LRU's for MOTV In-Orbit Replacement at SOC (Contd) – ECLS

QTY	LRU	
3	FUEL CELL	H_2O and REACTANT INTERFACE UNIT
3		ELECTRICAL HARNESS
3	ELECTROLYZER	
3	ELECTROLYZER	H_2O and REACTANT INTERFACE UNIT
3	ELECTROLYZER	ELECTRICAL HARNESS
3	OXYGEN TANK	
3	OXYGEN TANK	INTERFACE UNIT
3	HYDROGEN TANK	
3	HYDROGEN TANK	INTERFACE UNIT
3	WATER TANK	
3	WATER TANK	INTERFACE UNIT
2	REACTANT LINES NETWORK	
2	H_2O LINES NETWORK	
2	SOLAR ARRAY ASSEMBLY	
1	SOLAR ARRAY DRIVE ASSEMBLY	
2	SOLAR ARRAY POWER CONT & COND UNIT	
2	SOLAR ARRAY ELECTRICAL HARNESS	
2	BATTERY	
2	BATTERY	ELECTRICAL HARNESS
1	PROP. MODULE POWER CONT & DIST UNIT	
2	CABIN MODULE POWER CONT & DIST UNIT	
2	PROP/CABIN MODULE INTERFACE HARNESS	1776-845W

Fig. 6-5 Candidate LRU's for MOTV In-Orbit Replacement at SOC (Contd) – EPS

1) RR ELECTRONICS
2) RR RECEIVER DEMODULATOR
3) KU-BAND TRANSMITTER
4) RR DIPLEXER
5) RR 1.5' STEERABLE ANTENNA
6) X-BAND TRANSMITTERS (2) – *C
7) S-BAND TRANSMITTERS (2) – C
8) S-BAND RECEIVERS (2) – C
9) X-BAND 3.5' ANTENNA – C
10) TRANSFER RF SWITCH – C
11) X-BAND COMBINER – C
12) S-BAND ANTENNA STEERING – C
13) X-BAND ANTENNA STEERING – C
14) S-BAND OMNI ANTENNA – C
15) S-BAND 1.5' STEERABLE ANTENNA – C
16) S-BAND HYBRID COUPLER – C
17) S-BAND SUB-CARRIER OSCILLATORS – C
18) IMU – C
19) STAR SCANNER – C
20) HORIZON SENSOR – C
21) N&G SIGNAL CONDITIONERS (2) – C
22) TAPE RECORDER
23) DATA MANAGEMENT SIGNAL CONDITIONERS (2) – C
24) ECLSS SENSORS (2)
25) A/D CONVERTER – C
26) ELECTRONIC COMMUTATOR – C
27) PCM ELECTRONICS – C
28) CAUTION & WARNING ELECTRONICS – C
29) DATA DISTRIBUTION CENTER
30) DIGITAL INTERFACE UNIT
31) CONTROL PROCESSING UNIT (COMPUTER)
32) COMPUTER DISPLAY
33) COMPUTER KEYBOARD CALL-UP
34) CABIN C.B. PANELS
35) VIDEO CAMERAS (3)
36) MANIPULATOR STATION DISPLAY
37) CABIN S/S SWITCHES, CONTROLS AND INDICATORS
38) CAUTION & WARNING DISPLAY

*C = CORE. ALL REMAINING LRU's IN MAN MODULE

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Fig. 6-5 Candidate LRU's for MOTV In-Orbit Replacement at SOC (Contd) – Avionics System

	GND M HR	REDUCED TASK M HR	REDUCED TASK RATIONAL	M HR AT LEO X5	M HR AT LEO X11	NO. OF MEN	EQUIV HR	LEO DAYS	LEO/GND M HR
MAINT PREPS	101	40	LIMITED PREPS REQ'D	150	11				
				161		5	32	4	1.6
SCHEDULED MAINT									
INSPECTION (ALL SUBSYS) SCHEDULED REPLACEMENT & CALIBRION	84	60	SPECIAL TOOL & FASTENERS	210	20	6	38.3	4.8	2.7
ENGINE COMPONENTS & PROPULSION	56	39	SPECIAL TOOLS, FIXTURES & AUTOMATION	136	12				
ECLSS	28	17	SAME AS ABOVE		19	5	30.4	3.8	2.2
ELECTRICAL/AVIONICS	28	20	FEWER ASSEMBLIES & AUTOMATION	70	6				
SERVICE LEAK & FUNCTIONALS	98	69	ENVIRONMENT & AUTOMATION	172	38	6	35	4.4	2.14
SUB SYS, SYS & READINESS TESTS	100	100			110	9	12.2	1.5	1.1
SUBTOTAL (SCHED MAINT)	394	304		583	205				2.0
				793					
DROP TANK PROCESSING	45	–	NONE REQD AT LEO						
CORE DT INTEGRATION	16	–	NONE REQD AT LEO						
PREP FOR PAD	67.2	–	NONE REQD						
PAD OPERATIONS	32	–	NONE REQD						
ASSEMBLY OPERATIONS AT LEO	–	12		30	6	2	17.8	2.2	–
TOTALS	829	465		768	222				2.3
				990					
				1944					

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Fig. 6-6 SOC Turnaround Manpower Calculations

UNSCHEDULED MAINT	GND M HR	REDUCED TASK M HR	REDUCED TASK RATIONAL	LEO MANPOWER M HR EVA (15)	LEO MANPOWER M HR SHIRT SLEEVE (1.1)	LEO MANPOWER NO. OF MEN	EQUIV HR	LEO DAYS	LEO/GND M HR
REPAIR & N D T									
STRUCTURE & TITLE BLANKETS	102	61	LIMITED STRUCTURE & SPECIAL TOOLS						
MECHANICAL	72	–	REPLACE NO REPAIR						
ENGINE	60	--	REPLACE NO REPAIR						
FLUIDS (PROP/ECLSS)	109	21	FIX LEAKS ONLY						
AVIONICS & ELELECT	84	–	REPLACE NO REPAIR						
SUB TOTAL/AVE	427	72		288	16	8	38	4.75	0.7
				304					
DIAGNOSTIC TESTS									
PROP, ENG & ECLSS	118	100	REDUCED 0.15						
ELEC, EPS	78	66	BY MORE						
SUBTOTAL	196	166	AUTOMATION		182	7	26	3.25	0.93
REPLACEMENT									
STRUCTURAL BLANKETS	22	10	BLANKETS & SIMPLE SECONDARY STRUCTURE	50					
MECHANICAL	75	54		216	12				
ENGINE	81	56	TOOL, RIGS &	224	12				
FLUIDS, PROP/ECLSS	81	56	AUTOMATION						
AVIONICS/ELECT	88	68	HIGHER ASSEMBLIES	238	22				
SUBTOTAL	276	188		728	46	8	96.75	12	2.8
				774					
FURTHER INSP									
ALL SUBSYS	180	90	LIMITED & USE OF SPECIAL TOOLS	360	20	8	47.5	5.9	2.1
				380					
MOD & RECONFIGURE									
STRUCT/MECH	100	50	LIMITED TO REPLACE-						
FLUIDS/ENGINE	50	25	MENT OF MAJOR						
AVIONICS/ELECT	50	25	MODIFIED ASSEMBLIES						
BUS TOTAL AVE	200	100	WITH SPECIAL TOOLS	400	22	8	52.75	6.6	2.1
				422					
SUM TOTALS	1279	616		1776	240				1.6
				2062					

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Fig. 6-6 SOC Turnaround Manpower Calculations (Contd)

the various major task categories, Fig. 5-22. The results are listed for each of the applicable SOC tasks, Fig. 6-6, first column

3) The ground manhours, Fig. 6-6, are broken down by discipline for scheduled and unscheduled maintenance, which are the prime drivers

4) The baseline manhours are reduced assuming implementation of maintainability requirements as will be discussed in paragraph 6.3.1. These are tabulated in the second column along with the rationale, Fig. 6-5. These reduced manhours are still ground equivalent hours

5) The next two columns break down the reduced manhours relative to the portion accomplished IVA (shirt sleeve) or EVA and multiply them by 1.1 or 5,

respectively, to reflect the relative difficulty of operating in EVA. The factors were derived from NASA water tank tests, Skylab, and MRWS data. The manhours listed in the fourth and fifth columns of Fig. 6-6 are equivalent SOC LEO manhours

6) The remaining columns of Fig. 6-5 are self-explanatory and are used to calculate equivalent hours or days required to turnaround the MOTV at SOC.

The total number of direct LEO SOC manhours for MOTV is 4011, as compared to 2108 for ground "hands on" turnaround. The overall ratio of LEO/ground turnaround manhours is 1.9.

Figure 6-7 indicates the peak manpower loading for the major SOC activities, including the direct support provided by the ground support team during SOC turnaround. The ground support team provides the analysis, determination of corrective action and, with the help of the TV cameras, the QC function.

6.2.3 SOC Support Requirements

The functional requirements tabulated in Fig. 5-3 and Figs. 5-24 through 5-27,

ACTIVITY DESCRIPTOR	MAINT PREP	MAINTENANCE	ASSEMBLY & REFUEL	FINAL MISSION PREPS
ON VEHICLE				
ORBITER			1 RMS	
INSIDE CABIN	2 SHIRT SLEEVE (S/S)	2 S/S		3 S/S
OUTSIDE CABIN	1 EVA	3 OCP, 1 EVA		
AROUND INTER STAGE	1 OCP			
AROUND CORE	1 EVA	1 OCP	1 OCP	
DROP TANKS			1 EVA	
DIRECT SOC SUPPORT				
TEST CONSOLE (LPS TYPE)		1 S/S		1 S/S
GSE FLUID & ELECT		2 S/S	1 S/S	
DIRECT GROUND SUPPORT				
MAINT ANALYSIS CNTR	2 SUBSYSTEM SPECIAL	5 SUBSYS SPECIALIST	2 SUBSYS SPECIAL	2 SYSTEM SPECIAL
MAINT DIRECTOR	1	1	1	
TOTALS: SOC	5	10	4	4
GROUND	3	6	3	2
1776-849W				

Fig. 6-7 Peak Manpower Utilization for SOC Turnaround Activities

ground support, mechanical, transportation, fluid and avionics GSE, were used as a baseline to define a preliminary list of GSE. Typical scheduled and unscheduled maintenance tasks were also broken down and time-lined as an aid to defining support requirements.

Figure 6-8 breaks down the operations to remove and replace a partially damaged solar array (LRU). The scenario for this unscheduled maintenance task is: the MOTV (on-board) instrumentation has indicated and verified a failure in a solar array wing assembly; the array retraction system has failed such that the array cannot be retracted and stowed (it is assumed the array cannot be safely returned to ground via Shuttle in this condition and must be disposed of in LEO); it is further assumed that an array jettison/disposal pack that will safely deorbit the array is available in the SOC; the Solar Array Command disabled (shorted) at the MOTV side of the power transfer assembly prior to maintenance.

Figure 6-8 indicates the step by step maintenance operations required, together with the equivalent ground times for the tasks.

Figure 6-9 breaks down and time-lines the scheduled refueling of the core. The scenario assumes the Orbiter has docked to SOC, the transfer tank has been connected to the logistics module which contains the fuel transfer pumps, and the MOTV has secured from maintenance and is ready for refueling.

Figures 6-10 and 6-11 break down the engine removal and replacement steps for a standard ground and a SOC design. A savings of approximately 35% can be accrued through design changes. This action could either be a result of a planned removal based on the limited life of critical engine components, or an unscheduled maintenance action which results from either an in-flight OFI verified anomaly or as a result of a problem uncovered during a post-flight inspection.

The scenario for Figure 6-12 assumes the radiator has been damaged during a meteroid storm and the ground support crew decides to replace it as a result of analyzing the TV pictures taken during the post-flight inspection.

Figure 6-12 outlines the task steps and ground-equivalent times required to remove and replace a damaged radiator panel (LRU). The times given are for two system designs: one for a typical system designed for normal ground repair/replacement of major components; and the other for a system designed specifically for maintenance in space by a suited crewman. The "special" system incorporates such features as shutoff valves to isolate the damaged panel from the remainder of the Freon loop and

TASK	TIME, HR
1) PREPARE SOLAR ARRAY JETTISON/DISPOSAL PACK	0.5
2) PREPARE & C/O OCP	0.8
3) INSTALL JETTISON/DISPOSAL PACK & TOOLS ON OCP	0.1
4) MOVE SOC CRANE TO OCP & ATTACH	0.1
5) MOVE OCP TO SOLAR ARRAY LOCATION	0.1
6) INSTALL SOLAR ARRAY SHORTING PLUG	0.1
7) ATTACH OCP MANIPULATOR TO STOWAGE CONTAINER	0.3
8) MECHANICAL DISENGAGEMENT OF 3 POINT ATTACHMENT & ELEC. DISCONNECT OF STOWAGE BOX FROM MOTV	0.4
9) INSTALL JETTISON/DISPOSAL PACKAGE ON STOWAGE CONTAINER	0.5
10) PARK DAMAGED SOLAR ARRAY	0.1
11) RETURN OCP TO SOC	0.1
12) ATTACH OCP MANIPULATOR TO NEW SOLAR ARRAY	0.3
13) RETURN OCP TO SOLAR ARRAY LOCATION	0.1
14) INSTALL NEW SOLAR ARRAY ON MOTV	0.5
15) REMOVE SOLAR ARRAY SHORTING PLUG	0.1
16) VERIFY ELECTRICAL INTERFACE	0.2
17) RETURN OCP TO SOC	0.1
18) DEACTIVATE & STORE OCP	0.5
19) ORIENT & DE-ORBIT OLD SOLAR ARRAY	0.3
TOTAL =	5.2

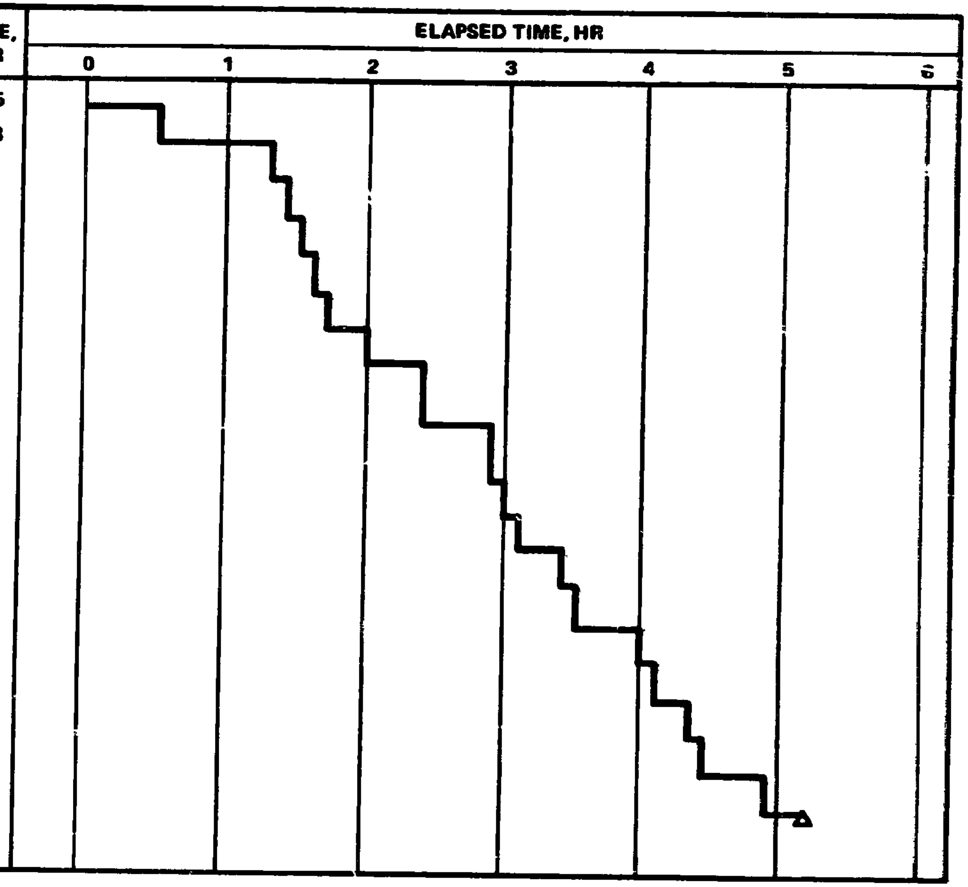

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Fig. 6-8 Solar Array Jettison/Disposal – Replacement

TASK	TIME, HR
1) PREPARE & C/O OCP	0.8
2) VENT LH_2 TANK (PARALLEL WITH 1.)	*0.5
3) TRANSFER LH_2 LINE TO MOTV & ATTACH.	*0.2
4) VENT LH_2 LINE	*0.1
5) FILL WITH LH_2	0.2
6) CHILLDOWN OF LH_2 TANK	0.3
7) VENT LH_2 TANK	0.5
8) REFILL LH_2 TANK	0.2
9) THERMAL HOLD	0.3
10) VENT LH_2 TANK	0.5
11) FINAL FILL LH_2	0.5
12) VENT & PURGE FILL LINE	0.2
13) DISCONNECT & RETURN LINE TO SOC	0.2
14) VENT LO_2 TANK	0.5
15) TRANSFER & ATTACH LO_2 LINE	*0.2
16) VENT LINE	*0.1
17) FILL TANK WITH LO_2	0.2
18) CHILLDOWN OF LO_2 TANK	0.3
19) VENT LO_2 TANK	0.5
20) FINAL FILL LO_2	0.5
21) VENT LO_2 LINE	0.1
22) DISCONNECT LINE & RETURN TO SOC	0.2
23) DEACTIVATE & STORE OCP	0.5
TOTAL =	6.5

* PARALLEL TASKS

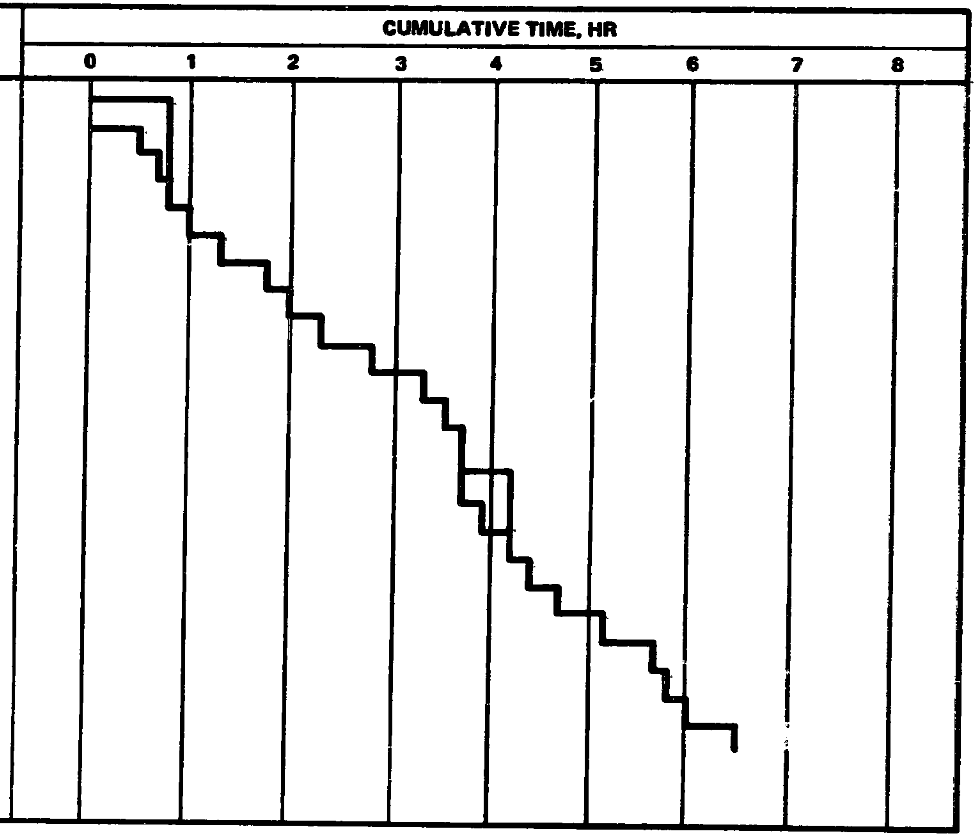

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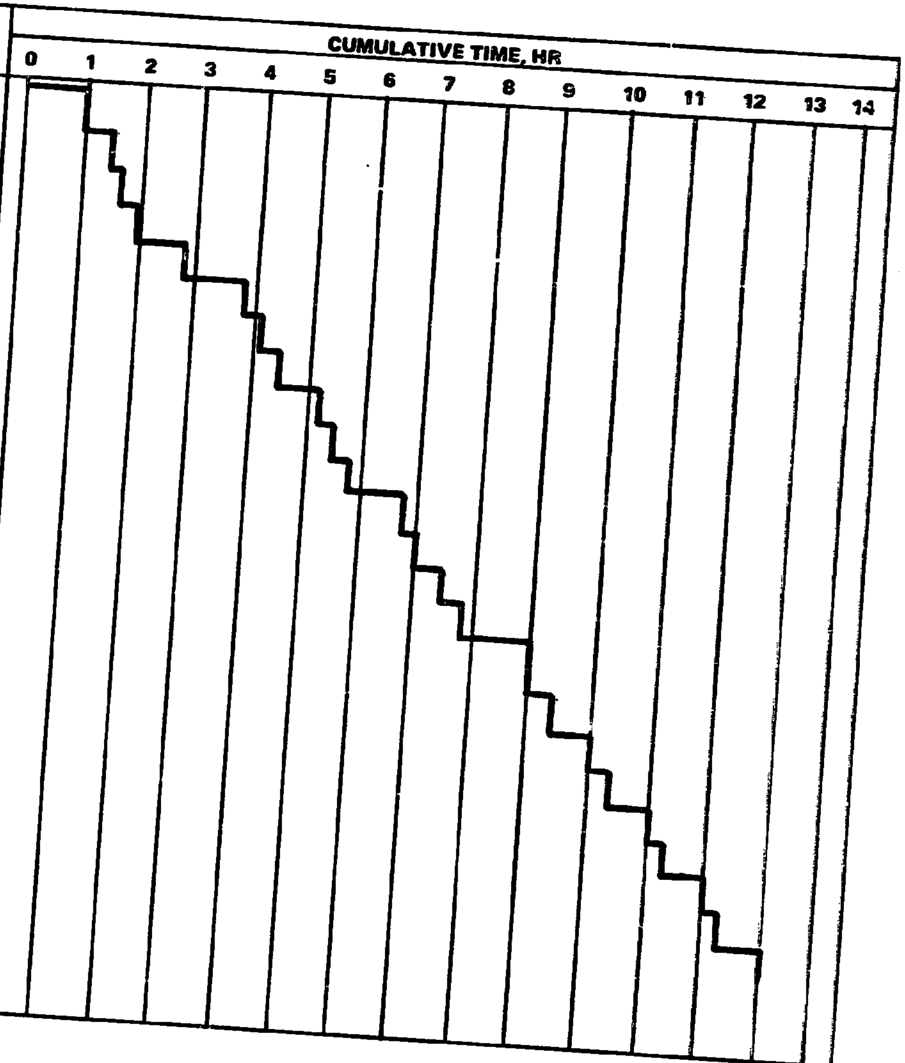
Fig. 6-9 Core Module – Refueling in LEO

TASK	TIME, HR
1) PREPARE HANDLING EQUIP. – PLUG, FRAME, DOLLY, COVERS	1.0
2) VENT FUEL & OX.	0.5
3) PURGE WITH He	0.2
4) VENT TO ATMOS	0.2
5) INSTALL HDLG PLUG	1.0
6) INSTALL HDLG FRAME	1.0
7) POSITION CRANE & ATTACH HOOK	0.2
8) DISCONNECT FUEL LINE	0.5
9) DISCONNECT OX. LINE	0.5
10) DISCONNECT PNEUM. & ELECT. LINES	0.2
11) DISCONNECT MECH ATTACH.	0.5
12) REMOVE ENGINE & INSTALL ON DOLLY	1.0
13) INSTALL COVERS	0.2
14) TRANSFER TO STORAGE AREA	0.5
15) REMOVE ENG FROM STORAGE & MOVE TO WORK AREA	0.5
16) REMOVE COVERS, ATTACH CRANE & DETACH FROM DOLLY	1.0
17) PLACE ON INSTALL. FIXTURE	0.5
18) INSTALL ENG & MAKE MECH CONNS	0.5
19) REMOVE HDGL FRAME	0.5
20) REMOVE HDLG PLUG	0.5
21) CONNECT FUEL INLET	0.5
22) CONNECT OX. INLET	0.5
23) CONNECT PNEUM. & ELECTRICAL INTERFACES	0.2
24) LEAK & FUNCT. CHECK ENGINE	0.5
25) STORE GSE	0.5
TOTAL =	13.2 HR



ADDED TIME DUE TO
- COMPLEXITY OF GSE AS SUPPLIED BY ENG MFG
- NO SPECIAL TOOLS
- NO SPECIAL HDLG & STORAGE PROVISIONS

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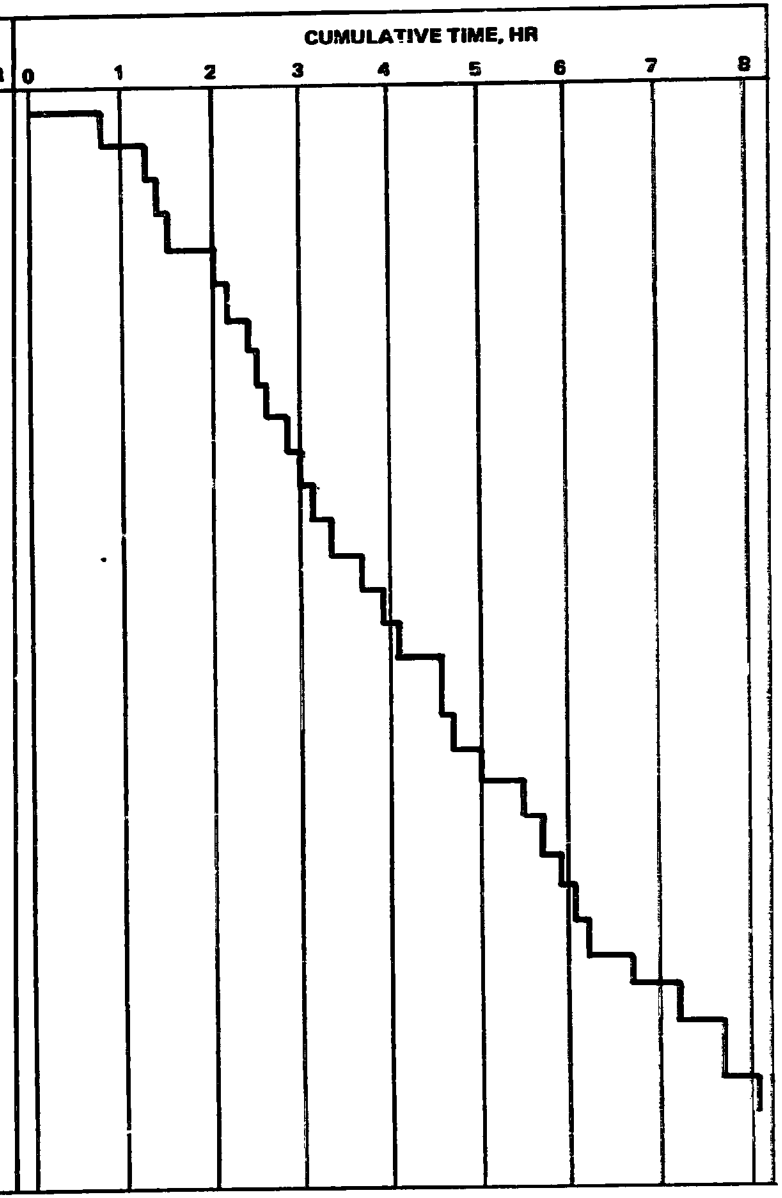
Fig. 6-10 RL10 Engine Removal/Installation on Ground

TASK	TIME, HR
1) PREPARE & C/O OCP	0.8
2) INSTALL ENGINE HDLG FIXT & TOOLS ON OCP	0.5
3) MOVE SOC CRANE TO OCP & ATTACH	0.1
4) MOVE OCP TO ENGINE LOCATION	0.1
5) INSTALL HDLG FIXT ON ENGINE	0.5
6) VENT FUEL & OX. FROM ENGINE FEED LINES	0.2
7) PURGE WITH He	0.2
8) VENT TO VACUUM	0.1
9) ATTACH OCP MANIPULATOR TO ENG HDLG FIXTURE	0.1
10) DISCONNECT FUEL LINE FROM MOTV	0.2
11) DISCONNECT OXID LINE FROM MOTV	0.2
12) DISCONNECT PNEUMATIC & ELECT. CONNS	0.1
13) DISCONNECT MECH SUPTS (GIMBAL & 2 ACTUATOR CONNS)	0.2
14) REMOVE ENGINE FROM MOTV & TRANSFER TO SOC	0.3
15) INSTALL ENGINE COVERS & PLACE IN STORAGE	0.3
16) REMOVE NEW ENGINE FROM STORAGE	0.2
17) REMOVE COVERS, INSTALL HANDLING FIXTURE & ATTACH TO OCP	0.5
18) TRANSFER ENGINE TO MOTV	0.1
19) INSTALL GUIDERAILS ON MOTV	0.3
20) ALIGN ENGINE WITH GUIDERAILS & INSTALL	0.5
21) CONNECT MECH. PINS - 3 PLS	0.2
22) CONNECT FUEL INLET – 16 BOLTS	0.2
23) CONNECT OXIDIZER INLET - 24 BOLTS	0.2
24) CONNECT PNEUMATIC & ELECT. INTERFACES	0.1
25) REMOVE INSTALL. & HDLG FIXTURES	0.5
26) LEAK & FUNCTIONAL CHECK ENGINE	0.5
27) TRANSFER FIXTURES & TOOLS TO SOC & PLACE IN STORAGE	0.5
28) DEACTIVATE & STORE OCP	0.5
TOTAL =	8.2



(NOTE: (2) MEN REQ'D – (1) CHERRY PICKER, (1) CRANE & MONITOR)

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Fig. 6-11 RL10 Engine Removal/Installation in LEO

TASK	TIME, HR GRND	SOC	Δ
1) PREPARE & C/O OPEN CHERRY PICKER	0.8	0.8	0
2) INSTALL HANDLING FIXTURE & TOOLS ON OCP	0.3	0.3	0
3) MOVE SOC CRANE TO OCP & ATTACH	0.1	0.1	0
4) MOVE OCP TO MOTV RADIATOR LOCATION	0.1	0.1	0
5) INSTALL HANDLING FIXTURE TO DAMAGED PANEL	0.3	0.3	0
6) CLOSE RADIATOR ISOLATION VALVES (SOC SYSTEM ONLY)	0	0.2	+.2
7) VENT FREON LOOPS TO SPACE (GROUND SYSTEM ONLY)	2.0	0	-2.0
8) DISCONNECT FREON LINES – (GROUND SYSTEM USED STANDARD COUPLINGS, SOC SYSTEM HAS SPECIAL QUICK RELEASE COUPLINGS INCORPORATED IN ISOLATION VALVES	1.0	0.2	-0.8
9) REMOVE PANEL FASTENERS & REMOVE PANEL FROM MOTV (GROUND SYSTEM USED STANDARD HARDWARE, SOC SYSTEM USES LATCHES)	1.0	0.2	-0.8
10) MOVE OCP TO SOC & EXCHANGE DAMAGED PANEL FOR NEW PANEL (SOC SYSTEM USES PRE-CHARGED FREON LOOP WITH SPECIAL SHUT-OFF VALVES AT CONNECTIONS; GROUND SYSTEM HAS EMPTY LIQUID LOOPS & STANDARD COUPLINGS	0.3	0.3	0
11) MOVE OCP TO MOTV, & POSITION AND INSTALL PANEL TO MOTV	1.0	0.2	-0.8
12) CONNECT FREON LINES	1.0	0.2	-0.8
13) FILL SYSTEM WITH FREON FROM RECHARGE BOTTLE (GROUND ONLY)	0.8	0	-0.8
14) LEAK CHECK FITTINGS (HALOGEN LEAK DETECTOR)	0.7	0.7	0
15) REMOVE HANDLING FIXTURE, RETURN TO SOC & DEACTIVATE	1.0	1.0	0
TOTALS =	10.8	4.6	-5.8

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Fig. 6-12 Radiator Panel – Remove & Replace

zero entrapment disconnects to facilitate replacing the damaged panel with a pre-charged panel, thereby eliminating the time-consuming venting and recharging of the Freon loops. In addition, special latch-type fasteners are incorporated to mount the panel to the MOTV structure to eliminate standard screw-type fasteners. The overall savings are approximately 55% with the system designed for SOC maintenance.

Figure 6-13 breaks down the unscheduled removal and replacement of a Rendezvous Radar Ku-Band Transmitter (LRU) in the cabin in a shirt sleeve environment as a result of an in-flight problem verified through the OFI parameters.

Figure 6-14 outlines the steps and times required for an unscheduled replacement of the Communications S-Band transmitter (LRU) from the core interstage area as a result of an in-flight discrepancy. Times indicated, as in every other case, are ground-equivalent times not adjusted for EVA or shirt sleeve environment.

It should also be noted that the breakdown of tasks was also used as check on the overall manpower calculations discussed in paragraph 6.2.2.

A preliminary list of SOC support equipment is given in Fig 6-15 and 6-16.

6.2.4 LEO SOC Turnaround Schedule

Figure 6-17 is a Level I schedule showing the typical number of days required to turnaround the MOTV; a total of 42 days is required.

6.2.5 SOC MOTV Facility Requirements

Figure 6-18 illustrates an overall concept for the SOC MOTV turnaround support facility. The changes and additions to the SOC facility listed below will be required to enable an MOTV turnaround in LEO.

1) Tubular Tunnel Extension, approximately 40 feet long, with berthing port at end for Space Shuttle docking and a berthing port for the MOTV Core Module alongside the tunnel

2) Servicing Tower mounted on the tunnel extension with provisions to rotate it from a position parallel to the Core Module to a position 90° from it

3) MOTV Logistics Module, mounted on a track system on the Service Tower to enable translation along it; the Logistics Module will have cargo bay doors to provide access to spare parts and support equipment carried within the Module

TASK	TIME, MIN.
1) REMOVE R.F. CONNECTOR FROM TRANSMITTER (LRU)	3
2) REMOVE OTHER ELECTRICAL CONNECTOR FROM TRANSMITTER (LRU)	3
3) OPEN LOCKING MECHANISM HOLDING LRU	6
4) SLIDE LRU OUT FROM ITS HOUSING ON GUIDE ROLLERS USING HANDLE ON FRONT OF LRU	3
5) USING HANDLE, PLACE LRU IN STORAGE PLACE	6
6) PICK UP NEW LRU BY HANDLE FROM STORAGE PLACE	6
7) ALIGN NEW LRU USING ALIGNMENT PINS WITH HOUSING FOR UNIT	3
8) ENGAGE GUIDE ROLLERS ON EACH SIDE OF LRU	3
9) SLIDE NEW LRU INTO PLACE USING FRONTAL HANDLE	3
10) CLOSE LOCKING MECHANISM HOLDING LRU IN PLACE	6
11) CONNECT POWER & SIGNAL CONNECTOR TO LRU	3
12) CONNECT R.F. CONNECTOR TO LRU	3
13) TURN RENDEZVOUS RADAR (R.R.) POWER ON	3
14) CHECK FOR TRANSMITTER POWER USING R.R. DISPLAYS	12
TOTAL =	63

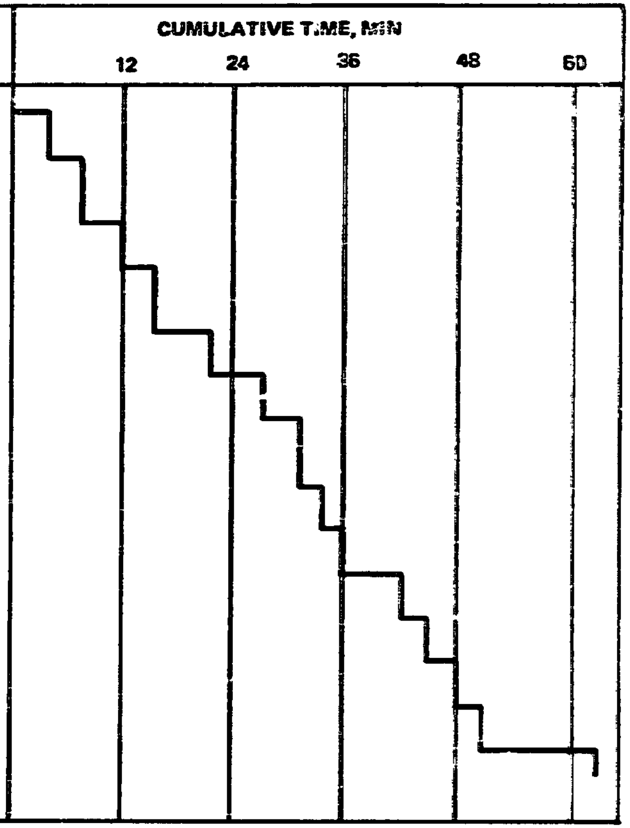

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Fig. 6-13 R.R. KU-Band Transmitter Removal & Replacement

TASK	TIME, MIN
1) PREPARE & C/O OPEN CHERRY PICKER	48
2) PLACE NEW S-BAND TRANSMITTER (LRU) & TOOLS ON OCP	18
3) MOVE OCP TO MOTV S-BAND TRANSMITTER LOCATION	6
4) REMOVE R.F. CONNECTOR FROM LRU USING UMBILICAN CONNECTOR TOOL	3
5) REMOVE POWER & SIGNAL CONNECTOR FROM LRU USING CONNECTOR TOOL	3
6) OPEN LOCKING MECHANISM HOLDING LRU USING PROPER TOOL	6
7) SLIDE LRU OUT FROM ITS HOUSING ON GUIDE ROLLERS USING FRONTAL HANDLE ON LRU	3
8) PLACE LRU ON OCP IN ITS STORAGE AREA USING FRONTAL HANDLE	3
9) PICK UP NEW LRU FROM OCP'S STORAGE AREA	3
10) ALIGN REPLACEMENT LRU USING ITS ALIGNMENT PINS WITH HOUSING FOR LRU	3
11) ENGAGE GUIDE ROLLERS ON EACH SIDE OF LRU	3
12) SLIDE NEW LRU INTO PLACE USING FRONTAL HANDLE	3
13) CLOSE LOCKING MECHANISMS HOLDING LRU IN PLACE	6
14) CONNECT POWER & SIGNAL CONNECTOR TO LRU USING UMBILICAL CONNECTOR TOOL	3
15) CONNECT R.F. CONNECTOR TO LRU USING CONNECTOR TOOL	3
16) TURN COMM S-BAND POWER-ON BY CABIN CREW MEMBER USING DIRECT. N FROM EVA ASTRONAUT VIA VOICE COMMUNICATION	6
17) CABIN CREW MEMBER CHECKS FOR S-BAND TRANSMITTER POWER USING COMM RADIATION DISPLAY	12
18) CABIN CREW MEMBER ADVISES EVA ASTRONAUT BY VOICE COMM THAT REPLACEMENT LRU WORKS	6
19) RETURN OCP TO SOC & DEACTIVATE	60
TOTAL TIME =	196 MIN

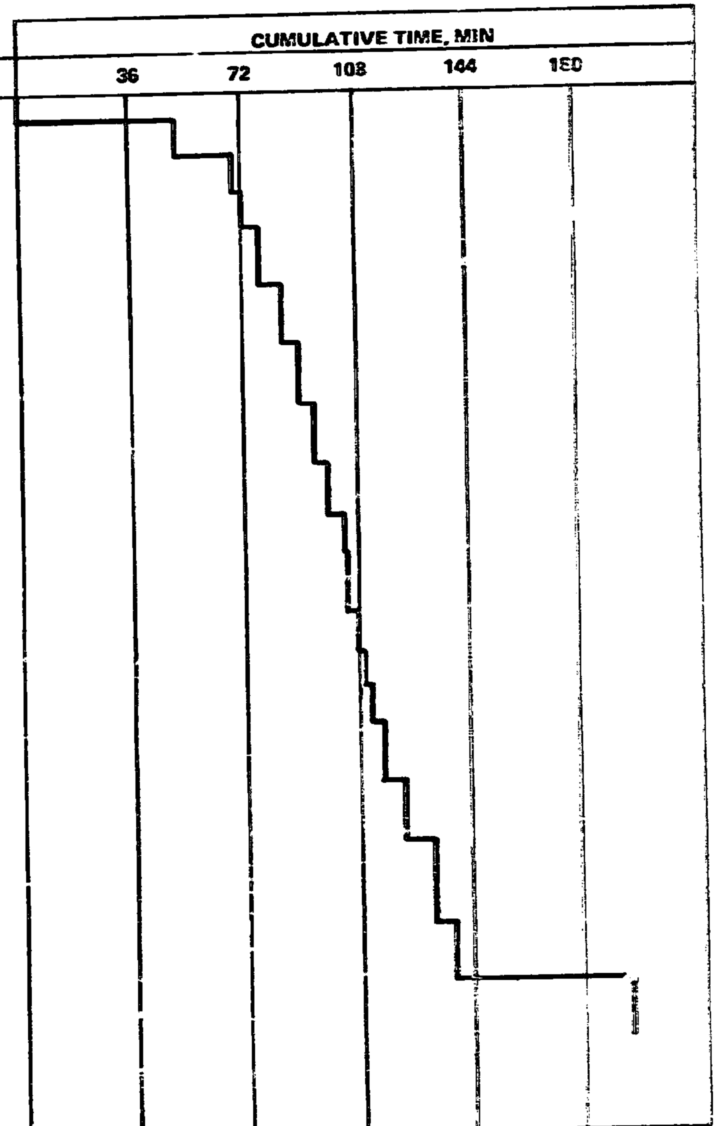

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Fig. 6-14 Communication S-Band Transmitter Removal and Replacement

1)	CABIN AIR SUPPLY UNIT	$300,000
2)	GROUND COOLING UNIT	450,000
3)	CABIN LEAK TEST UNIT	250,000
4)	ECLSS CHECKOUT UNIT	400,000
5)	GOX SERVICE UNIT	375,000
6)	GN_2 SERVICE UNIT	250,000
7)	LH_2 SERVICE UNIT	1,000,000
8)	LO_2 SERVICE UNIT	1,000,000
9)	CRYO SYSTEMS C/O UNIT	600,000
10)	WATER STORAGE & TRANSFER UNIT	450,000
11)	LEAK DETECTOR UNIT	100,000
12)	PROPULSION SYSTEM C/O UNIT	400,000
13)	HYPERBOLIC SERVICING UNIT – (1) FUEL	625,000
	– (2) OXIDIZER	625,000
14)	HELIUM PRESSURIZATION UNIT	350,000
15)	PURGE & DRYING UNIT	300,000
16)	FUEL CELL SERVICING UNIT	750,000
17)	WASTE MGMT SYST SERVICING UNIT	300,000
18)	Q.D./FILTER SET	200,000
1776-857W		$8,725,000

Fig. 6-15 Space Support Equipment – Fluid

1)	CORE MODULE/SOC INDEXED TURNTABLE	$800,000
2)	DROP TANK HANDLING FIXTURE	200,000
3)	DROP TANK/CORE MODULE ATTACHMENT TOOL SET	50,000
4)	ENGINE HANDLING/INSTALLATION FIXTURE	200,000
4)	RMS/ENGINE ADAPTER	50,000
6)	ENGINE ATTACHMENT TOOL SET	50,000
7)	ENGINE COVER	40,000
8)	ENGINE THROAT PLUG	100,000
9)	ENGINE/LOGISTIC MOD SUPPORT FIXTURE	200,000
10)	DROP TANK/CARGO BAY INTERFACE FIXTURE	250,000
11)	ELECTR LRU INSTALL. TOOL	50,000
12)	SOLAR ARRAY HANDLING FIXTURE	250,000
13)	SOLAR ARRAY PROTECTIVE COVER	50,000
14)	SOLAR ARRAY INSTALL. TOOL SET	50,000
15)	BORESCOPE/TV CAMERA INSPECTION SYSTEM	500,000
16)	RCS HANDLING FIXTURE	100,00
17)	RCS PROTECTIVE COVER	40,000
18)	RCS INSTALL. TOOLS	40,000
19)	RCS THROAT PLUG	50,000
1776-858W		$3,120,000

Fig. 6-15 Space Support Equipment (Contd) - Mechanical/Handling

ITEM	GROUND	COST	SOC	COST	WEIGHT
1) CAUTION & WARNING ELECTRONIC ASSEMBLY STIMULI GENERATOR	X	50K			
2) RENDEZVOUS RADAR TEST BENCH	X	100K	X	$1M	16 LB
3) ATTITUDE CONTROL & DETERMINATION TEST STATION	X	50K			
4) COMMUNICATION CHECKOUT & MAINTENANCE TEST STATION	X	100K			
5) AUDIO CENTER DEVELOPMENT TEST STATION	X	50K			
6) DISPLAY & CONTROL CONSOLE	X	100K			
7) PULSE CODE MODULATION & TIMING EQUIPMENT	X	50K			
8) INSTRUMENTATION STIMULI GENERATOR	X	50K			
9) S/C STATUS ACQUISITION SYSTEM	X	50K			
10) TV SYSTEM TEST SET	X	50K			
11) S-BAND UPLINK AND DOWNLINK TEST SET	X	100K	X	$1M	8
12) S-BAND, X-BAND, KU-BAND ANTENNA MAINT TEST STATION	X	100K	X	$1M	10
13) DISPLAYS & CONTROL MAINTENANCE TEST STATION	X	100K	X	$½M	12
14) PRN RANGING TEST SET	X	100K			
15) X-BAND DOWNLINK DATA TEST SET	X	100K	X	$½M	6.0
16) DC TRANSIENT VOLTAGE POWER SUPPLY	X	50K			
17) CONSTANT CURRENT BATTERY CHARGER	X	50K			
18) INVERTER SIMULATOR	X	50K			
19) ELECTRICAL LOAD SIMULATOR	X	50K			
20) VEHICLE GROUND POWER SUPPLY	X	50K	X	$100K	8
21) BATTERY MAINTENANCE TEST STATION	X	100K	X	$150K	5
22) ENVIRONMENTAL CONTROL SYSTEM TEST STATION	X	50K			
23) REACTION CONTROL S/S CONTROL STATION	X	50K	X	$¼M	4
24) HELIUM PRESSURIZATION CONTROL UNIT	X	50K			
25) RCS PRESSURIZATION CONTROL STATION	X	50K			
26) RCS FIRING CONTROL STATION	X	50K	X	$¼M	5
27) MAIN PROPULSION ELECTRICAL TEST SET	X	50K	X	$¼M	5
28) DIAGNOSTIC AUTOMATED TEST COMPUTER			X	}	7
29) DIAGNOSTIC COMPUTER DISPLAY			X	$4M	12.0
30) COMPUTER KEYBOARD CALL-UP			X	}	8.0
31) POWER SOURCES SIMULATOR			X	$½M	15.0
32) BATTERY CHECKOUT TEST/ DIAGNOSTIC STATION			X	$1M	12
		TOTAL = $1.8M		TOTAL = $10.5M	133 LB TOTAL

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Fig. 6-16 SOC GSE Electrical

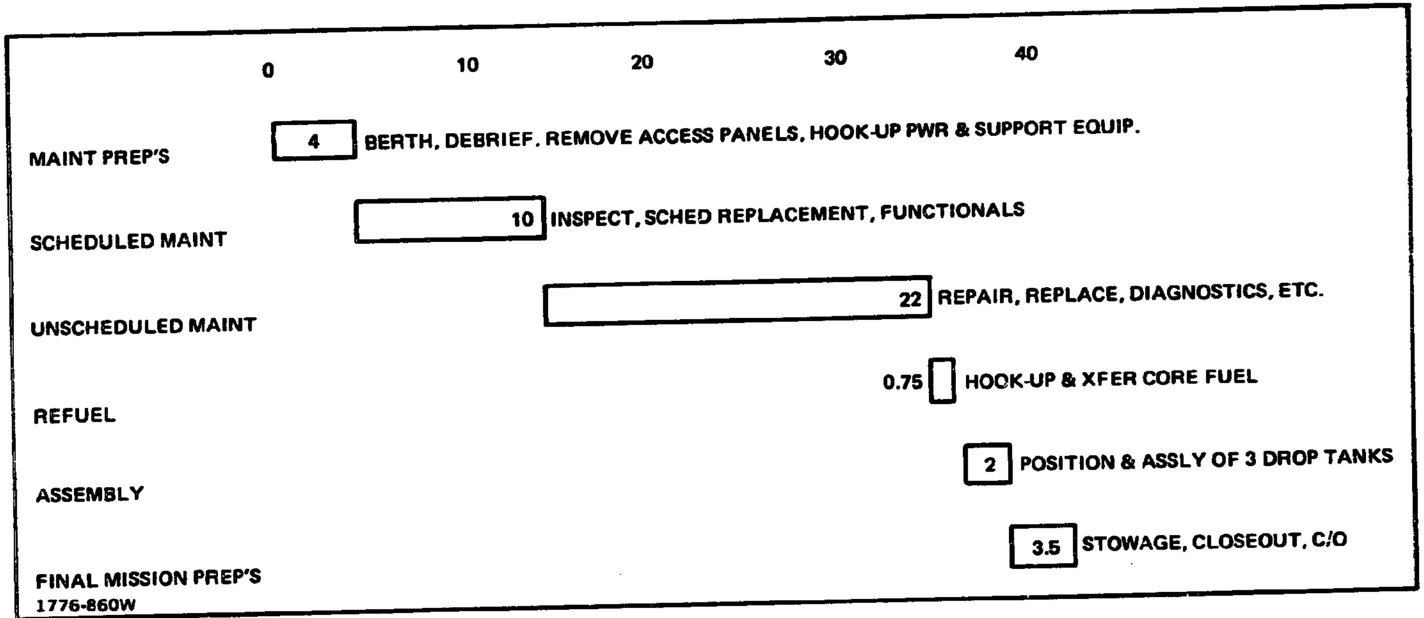

Fig. 6-17 LEO SOC Turnaround Schedule, Days

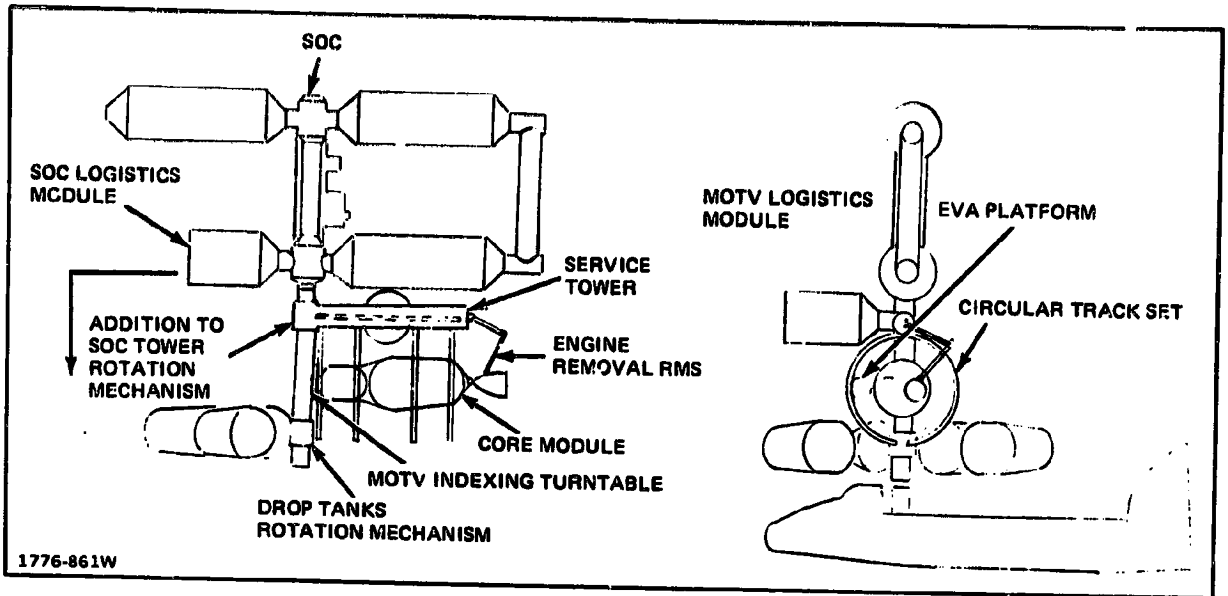

Fig. 6-18 SOC Facility Modifications for MOTV Turnaround

4) Four sets of circular tracks mounted to Service Tower that can be extended to completely enclose Core Module; tracks can translate along Core Module to any desired location

5) Four Open Manned Work Stations, one on each of the circular tracks, provide manned EVA access to complete exterior of Core Module

6) RMS mounted at end of Service Tower enable transfer of Main Engine between MOTV and Logistics Module

7) Indexed turntable mounted at Core Module berthing port enables rotation of Core Module to predetermined locations for installation of Drop Tanks

8) Drop Tank Rotation Mechanism attached to Tunnel Extension near Shuttle Berthing Port; Drop Tanks will be stocked in a radial pattern on mechanism and rotated in sequence for attachment to Core Module.

6.2.5.1 Engine Replacement in LEO. Changeout of a main MOTV engine can be accomplished in LEO utilizing the SOC. To enable engine changeout, a spare engine will be carried in the Logistics Module of SOC, complete with an engine handling fixture and other items of SSE. The engine will be completely checked out and certified on the ground.

The changeout would be a two-man operation. One man would be EVA and the other would operate the RMS and monitor the changeout operation. The first step would be to open the Logistic Module doors, position the EVA astronaut in the Logistic

Module, attach the RMS to the handling fixture, and move the handling fixture to the engine that has to be replaced (see Fig. 6-19).

The astronaut would then move to the OCP mounted on the circular rail adjacent to the engines. He would install the fixture on the engine, disconnect the fluid, electrical, and mechanical connections, and guide the engine as the RMS moves it away from the core module.

He would then return to the Logistics Module, guide the engine to the storage space provided for it in the Module, attach it to the Module, remove the RMS connection and attach it to the space engine. He would then detach the engine from its mounts and guide it as the RMS removes it from the Module.

The Astronaut would then return to the OCP at the MOTV engine location, install guide rails for the engine, assist the RMS in guiding it into place, and attach the mechanical connections. The guide rails and handling fixture would then be removed and the fluid and electrical lines connected. A leak and functional check would then be made, in conjunction with the man in the cabin, and the support equipment would be stowed in the Logistic Module. For the Engine Removal Timeline, see Fig. 6-11.

6.2.5.2 Drop Tank Installation in LEO. The Drop Tanks will be installed on the Core Module in LEO utilizing the SOC. The tanks will be transported individually into LEO by the Space Shuttle. They will be transferred from the Shuttle Cargo Bay to the SOC by the Shuttle RMS, see Fig. 6-20.

The tanks will be attached to a rotation mechanism on the SOC Tunnel Extension and stored at this location until the Core Module has been completely checked out and refueled. The tanks will then be rotated, one at a time, in a position adjacent to the Core Module. It will then be translated laterally until the mechanical, fluid, and electrical connections are automaticaly latched. The Drop Tank will then be disconnected from the Rotation Mechanism and the Core Module rotated to predetermined position, utilizing the indexing turntable on the SOC. The process will then be repeated for each additional Drop Tank.

6.2.5.3 LRU Replacement. The communications S-Band transmitter removal from the core module is time-lined in Fig. 6-14. Figure 6-21 illustrates the removal by an astro-worker using a special umbilical connector tool and the SOC service structure with the OCP work stations.

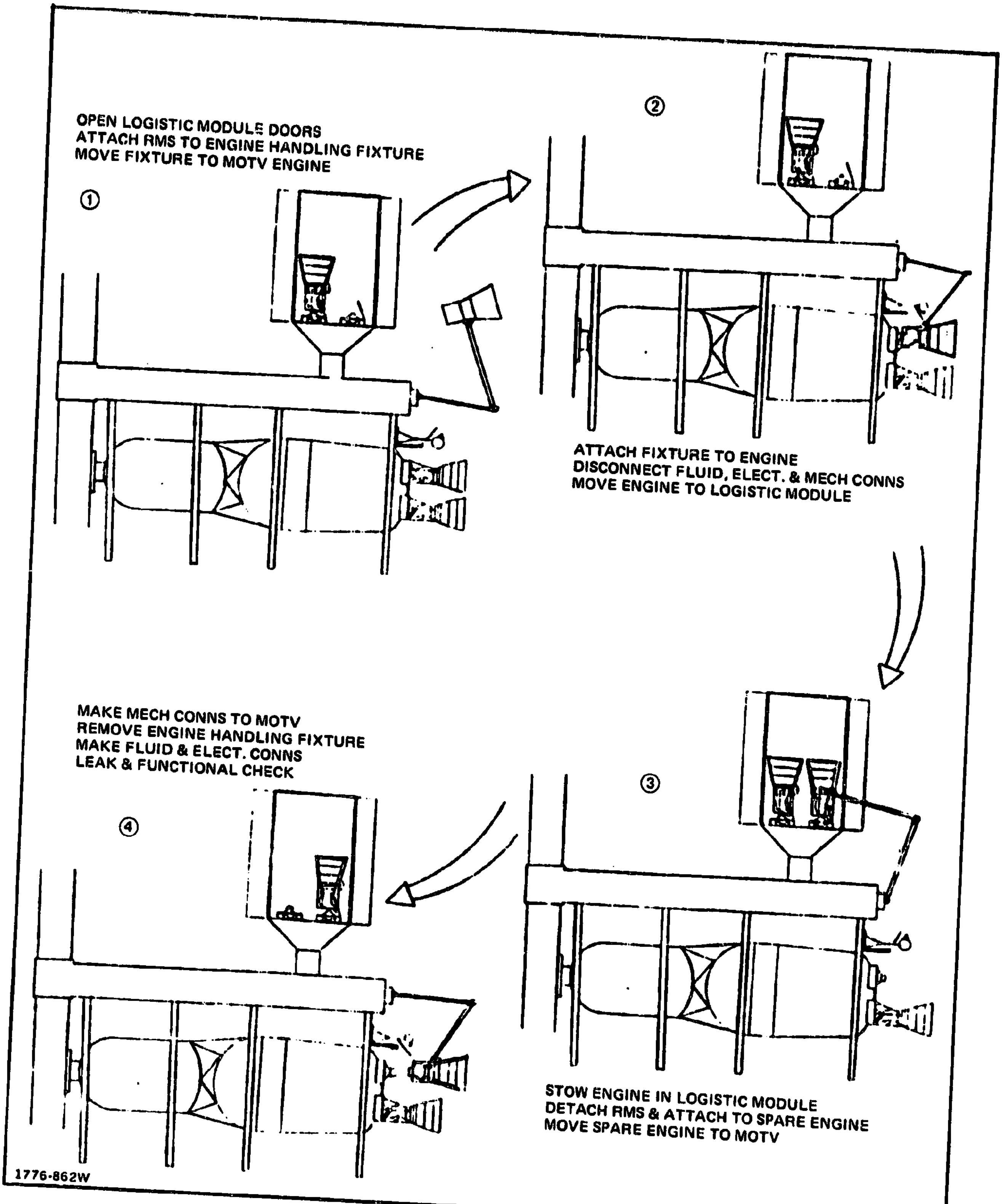

Fig. 6-19 Engine Replacement in LEO SOC

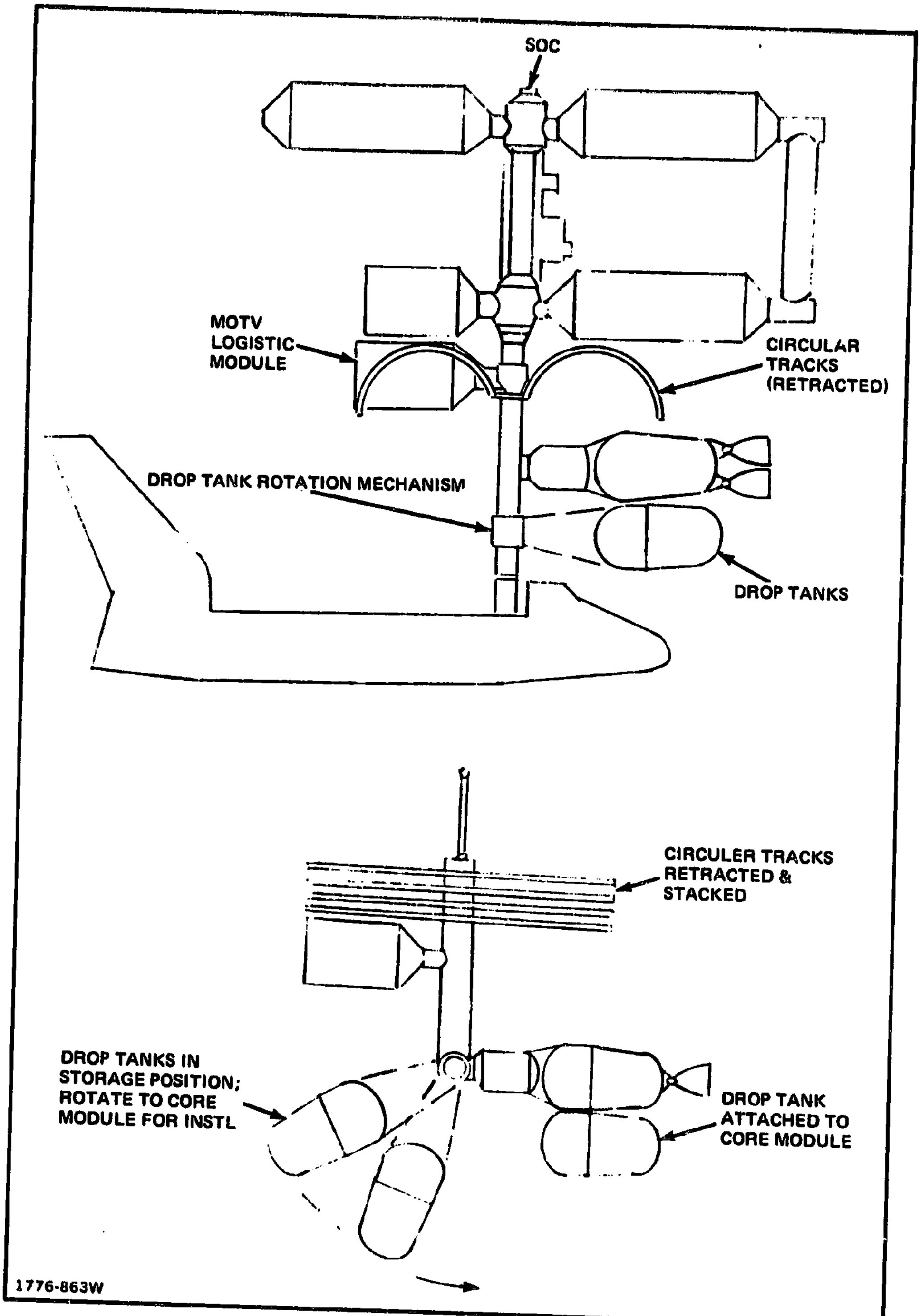

Fig. 6-20 Drop Tank Installation in LEO SOC

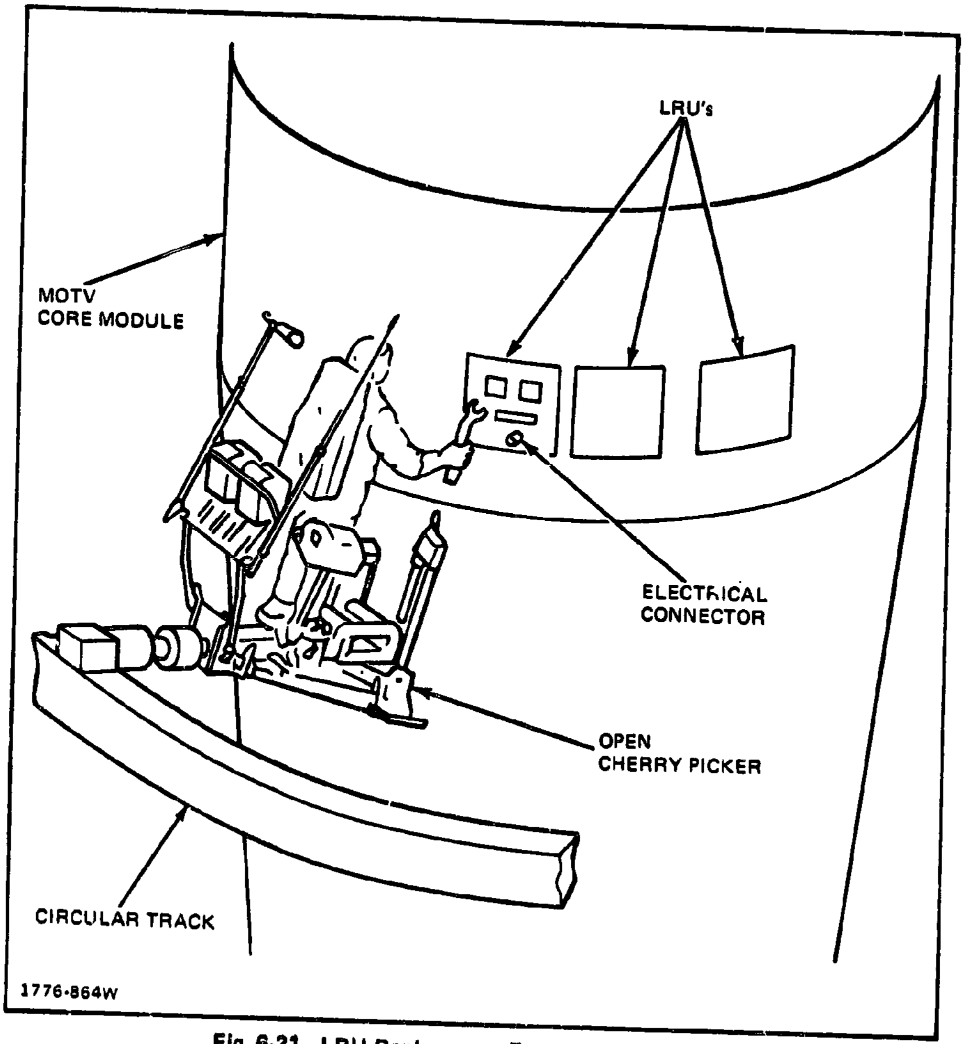

Fig. 6-21 LRU Replacement External to Core Module

7 - ANALYSIS OF TURNAROUND RESULTS

Analysis of turnaround results underscores the following:

- The primary turnaround support driver is maintenance
- Turnaround support requirements are very sensitive to
  - maintenance approach that includes philosophy, checkout autonomy, accessibility, and management
  - turnaround location that includes ground-based, LEO Shuttle-tended or LEO SOC-based
- MOTV costs per flight are sensitive to transportation costs which are influenced by turnaround location.

The following paragraphs analyze and discuss these issues.

7.1 MAINTENANCE IMPACT ON SUPPORT REQUIREMENTS

The manpower, support, equipment, and facility requirements developed for ground, Shuttle-tended, and SOC have one thing in common. The majority of the men and materials are required for maintenance with unscheduled maintenance requiring the major share. Figures 5-21, 5-30, and 6-3, functional requirements for ground based, Shuttle-tended, and SOC all support this as do the support equipment lists for ground and LEO operations discussed in the previous paragraphs. Maintenance also impacts the MOTV design, i.e., OFI, accessibility, and maintainability requirements will all influence the design. The impact on weight, sophistication, reliability, and cost will be assessed as the subsystem designs mature.

One further point should be made relative to the maintenance items listed in Figs. 5-21, 5-30, and 6-3. The purpose of these functional maintenance requirements is to drive out support requirements and size the personnel and materials necessary to support MOTV turnaround. Manhours, projected schedules, and manpower levels are sized to accommodate the scheduled, plus an average of the unscheduled, activities. For any particular flight, if OFI and a thorough inspection indicate all subsystems are go, a real time decision could be made to waive all further scheduled maintenance, service, refuel, assemble, and prep for the next flight.

7.2 TURNAROUND SENSITIVITY TO APPROACH

Turnaround manpower, manhours, schedule, and equipment requirements are sensitive to the approach, i.e., philosophy, checkout autonomy, and accessibility provided.

Figure 7-1 summarizes the difference in approach which generated the preliminary turnaround requirements, Fig. 3-5, and the updated baseline, Fig. 5-21.

Figure 7-2 shows the manpower sensitivity to changes in ground turnaround approach. It illustrates the manpower difference between the preliminary and updated data, i.e., maintenance prep, unscheduled maintenance, scheduled maintenance, integration of the core/manned module with the drop tanks for fit and functional checks, final preparation prior to shipment and the pad, and assembly operations at LEO. The bar chart shows that the estimated manhours are less for each category except assembly at LEO, which is common to both. It shows a decrease of about 30% in the number of direct line personnel required. Scheduled maintenance reflects the greatest reduction in manhours, about 45% for the updated baseline because of the use of flight data and inspections with increased accessibility rather than ground tests to determine the status of the modules. The decrease in peak manpower loading reflects better accessibility, less ground tests, and the use of systems engineers rather than subsystems specialists to cover the initial maintenance analysis, vehicle tests, and operations. In the updated ground operations approach, subsystem specialists support the system engineers and determine corrective action and retest for contingencies which are not covered by standard procedures. In addition to decreasing the direct manpower requirements associated with ground turnaround, the updated ground turnaround baseline does the following:

- Decreases mission abort risk by providing greater subsystem information
- Decreases the overall schedule and number of ground tests necessary by using flight data coupled with inspections for condition monitoring
- Provides maintenance assessment data prior to landing, thereby providing maximum time to assemble required resources
- Builds on the basic MOTV data management and telemetry subsystems to improve checkout autonomy.

	PRELIM BASELINE	UPDATED BASELINE
PHILOSOPHY	NONE	CONDITION MONITORING + MINIMAL TIME LIMIT
AUTOMATION	AUTOMATED GND EQUIP + STD OF I, GND DATA PRIME MAINT. ANALYSIS TOOL	AUTOMATED GND EQUIP + MAXIMUM OF I, FLT DATA PRIME MAINT ANALYSIS TOOL
ACCESSIBILITY	STD	MAXIMUM EXTERNAL & INTERNAL (BORESCOPE TYPE)
MANAGEMENT	TEAM SUBSYSTEM SPECIALISTS ON LINE	TEAM SYSTEM ENGINEERS ON LINE

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Fig. 7-1 Ground Turnaround Update vs Preliminary Baseline

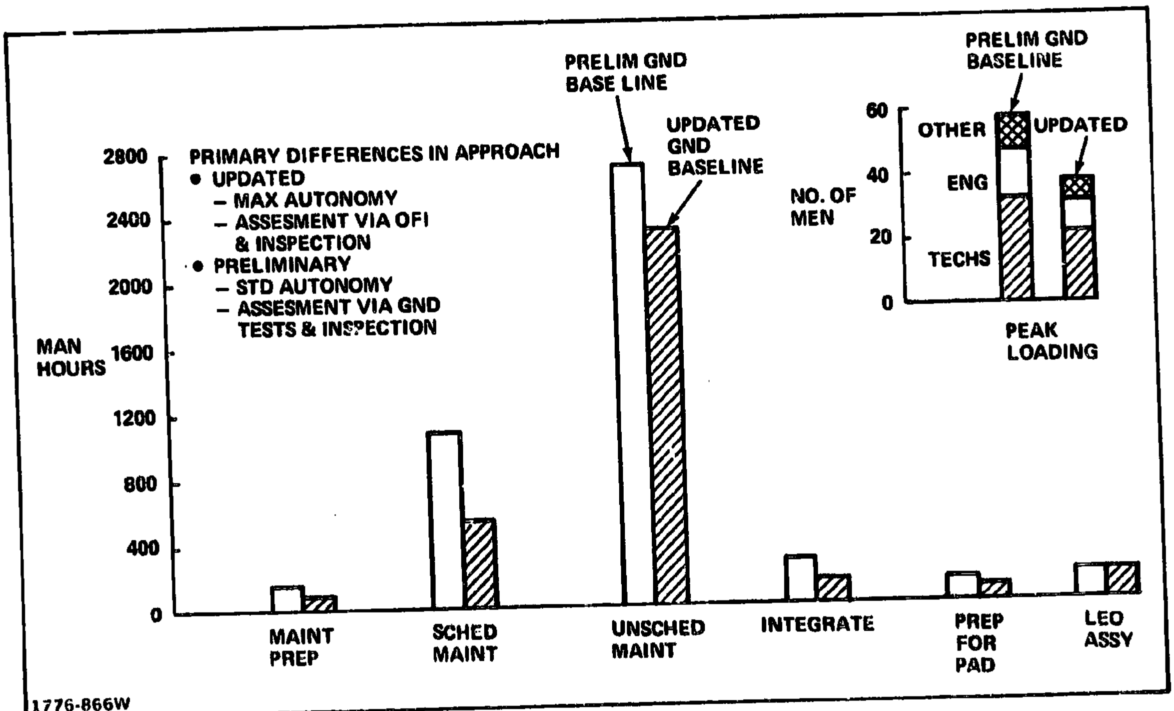

Fig. 7-2 Manpower Sensitivity to Change in Ground Turnaround Approach

7.3 TURNAROUND SENSITIVITY TO LOCATION

Location of the turnaround operations on the ground vs at LEO will have the most significant impact on the turnaround parameters, i.e., manpower, schedules, support equipment, and facilities.

7.3.1 Manpower Sensitivity

Figure 6-6 indicates that, although the equivalent ground task could be reduced by a significant amount through design and management techniques, the overall manpower requirements would be increased for LEO operations because of the relative difficulty of working at LEO vs the ground. Figure 7-3 illustrates the overall growth in manhours for each major activity; it is summarized as follows:

ACTIVITY	STD GND, M HR	LEO GND, M HR	LEO EQUIV, M HR
Unscheduled Maint	1279	616	2062
All Others	829	465	1949
Totals	2108	1081	4011

The above indicates that, although the turnaround effort, manhours, can be decreased by 50% (LEO GND/STD GND) through design, special tools, automation, and operational techniques, the net effect STD GND/LEO EQUIV is a 50% increase in the manhours required for turnaround.

7.3.2 Peak Manpower Requirements

Figure 6-7 indicates the manpower estimated to perform the SOC turnaround. It includes the "hands on" personnel at SOC and the direct vehicle support team on the ground required to work on a single shift basis. For the peak unscheduled maintenance, 10 men are required at SOC with six ground support personnel. Manpower at SOC was reduced to a minimum because of the transportation costs. This is about one-third of the manpower assigned to the ground operations, Fig. 5-22.

7.3.3 Schedule Sensitivity

Figure 7-4 shows the difference in schedule (total serial time) times for the ground, Shuttle-tended, and SOC. Shuttle-tended is the least efficient, taking approximately 60 days. SOC takes approximately 42 days for the complete turnaround operations, which is three-times as much as ground operations. The significant difference in schedule is due to the difference in the number of people used and the difference in the efficiency of the turnaround crew in LEO vs ground.

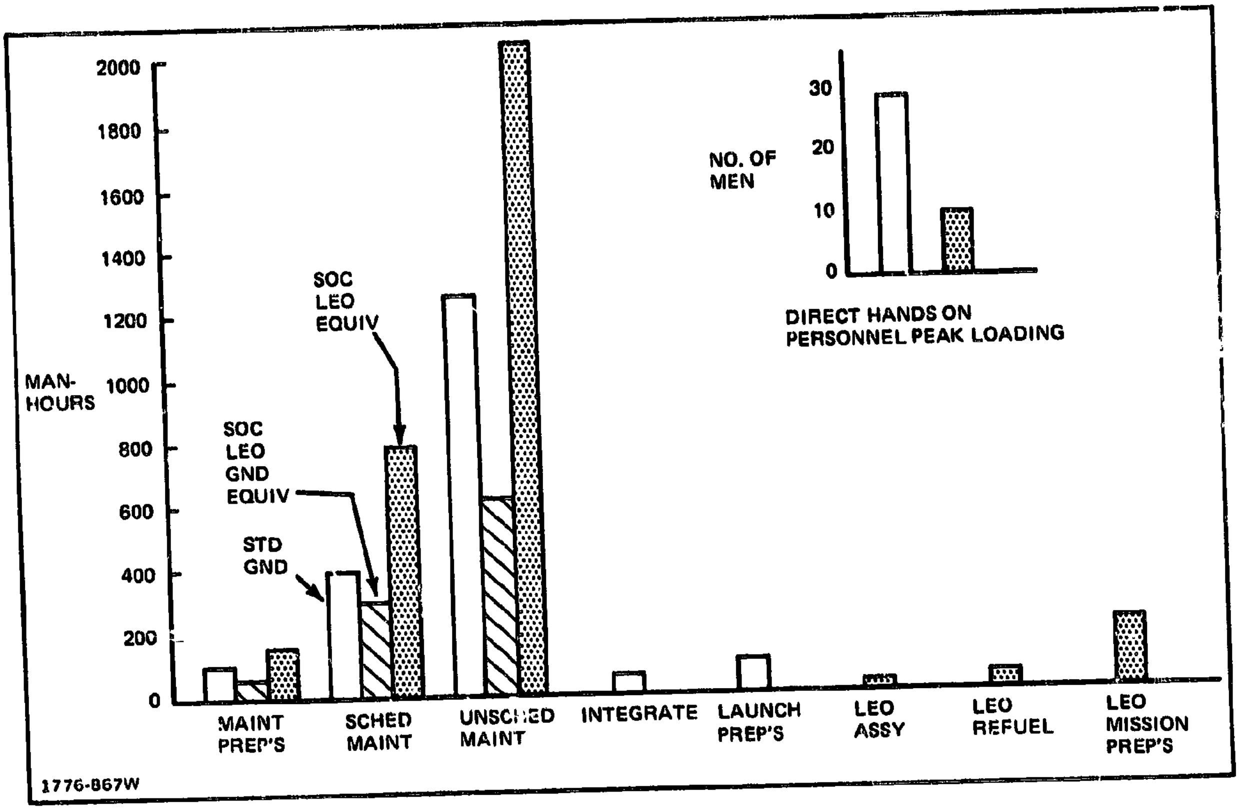

Fig. 7-3 Manpower Sensitivity to Turnaround Location

	GROUND TOTAL	LEO STS TENDED DAYS PER FLT				LEO SOC DAYS PER FLT			
		1	2	3	4	1	2	3	4
1) MAINT PREPS	2.8	2.8	0.73	0.73	0.73	4.0			
SER	2.5								
2) SCHEDULED MAINT									
INSPECTION	0.8	4.8				4.8			
REPLACEMENT & CAL	2	3.8				3.8			
LEAK & FUNCTIONALS & SERV	1.5	4.4				4.4			
SUB, SYS & READINESS TESTS	0.625			1.5		1.5			
SERIAL TIME	3.5	11				10			
3) UNSCHEDULED MAINT									
REPAIR	3		3.1	1.7		4.75			
DIAGNOSTIC TESTING	0.8		2.1	1.2		3.25			
REPLACEMENT	2		7.9	4.1		12			
FURTHER INSPECTION	2		3.8	2.1		5.9			
SYS MAD's & RECONFIG	2		4.3	2.3		6.6			
SERIAL TIME			2.0	10		22			
4) DROP TANK PROCESSING	2								
5) CORE/DROP TANK INTEG	0.625								
6) PREP FOR PAO	3.5								
7) INSTALL, C/O FUEL & LAUNCH	1.5								
8) SECURE		0.5	0.5	0.5	2.2				
REFUEL					0.75				0.75
9) ASSEMBLY AT LEO's	2.2	0.72	0.72	0.72		2.2			
10) FINAL MISSION PREP'S AT LEO									
STOWAGE				1.1	2.5				1.2
SERVICE			1.1	0.8	0.5				1.8
TESTS					0.4				0.4
11) TOTAL SERIAL TIME, DAYS	13.6	15	23	15	7	38			4
TOTAL SERIAL TIME, HOURS	109								

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Fig. 7-4 Turnaround Activity Times (Sched Time Comparison)

7.3.4 Overall Turnaround Schedules

Figure 7-5 is a comparison of the overall S-1 mission scenarios ground, STS-tended, and SOC. It shows the number of flights and turnaround schedules for each of the options. For each option a single STS is assumed to be available to support MOTV missions.

The ground turnaround option shown is for the decoupled mode, i.e., the returning MOTV is retrieved by the loitering shuttle and the next mission starts up after a given period of time (indicated by X). The ground portion of the turnaround has also been shown decoupled from the preparation of the next flight. With two MOTV's in the inventory, one is always taken out of storage in time for a new mission startup and the returning MOTV is secured, put into storage, and then prepared on a schedule consistent with the mission schedule. Since the MOTV ground turnaround falls well within the Shuttle ground turnaround, this decoupled mode poses no problems.

Some specific observations can be drawn from these scenarios. Figure 7-5 indicates the ground and SOC mission turnaround schedules are established by the dedicated Shuttle turnaround schedule, and not by the MOTV activities. In fact, for SOC the first Shuttle support flight bringing up the first Drop Tank must take place during the mission if the last Shuttle bringing up the transfer fuel tank is to arrive when required. For both of these options, decreasing the actual MOTV turnaround activities will not affect the overall S-1 turnaround schedule. If a second Shuttle vere added, then SOC could be constrained by MOTV but ground-based would not.

The STS-tended turnaround schedule, on the other hand, is constrained by the IOTV activities and reducing these would shorten the MOTV turnaround. For example, if unscheduled maintenance were not required between flights because all systems jere "go," the overall turnaround schedule could be reduced from approximately 102 o approximately 64 days. The limit would be determined by the four Shuttle flights, he time for minimum scheduled maintenance service, refuel, and assembly, which ould be approximately 58 days.

Figure 7-5 indicates that SOC can minimize the mission turnaround time, 42 vs 3, for ground-based by bringing up the first of the Drop Tanks to SOC prior to eturn of the MOTV to SOC. The Drop Tank cannot be brought up too early because boil-off considerations.

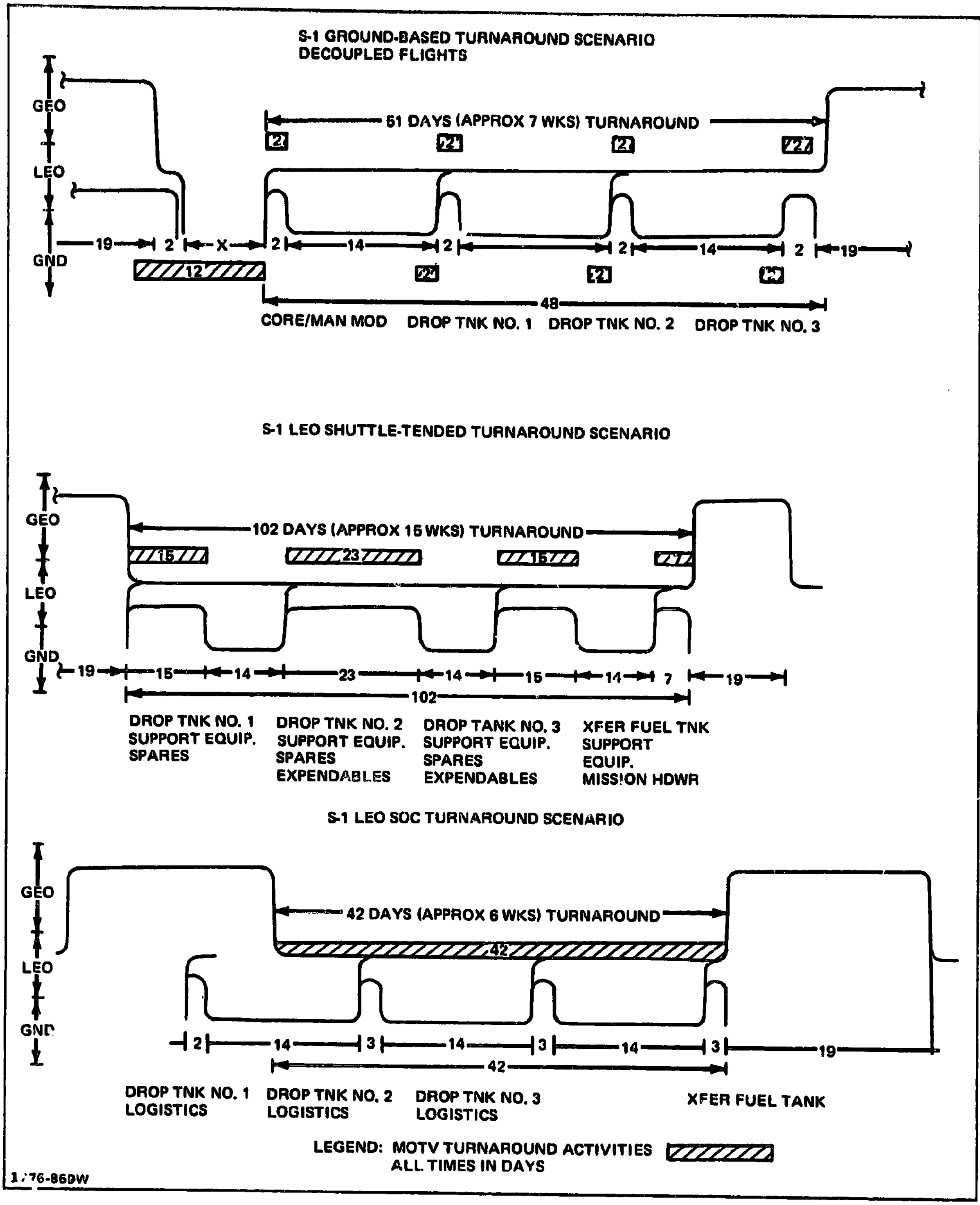

Fig. 7-5 Comparison of S-1 Turnaround Options

STS TRANSPORTATION REQUIREMENTS

Figure 7-6 tabulates the loading requirements for each of the STS flights for h of the options. It shows the flights and all major elements required for support, luding extra maintenance personnel. The last column in each option summarizes pertinent information across the page, i.e., 25 (for ground turnaround) is the nber of days the MOTV is charged with. For ground turnaround each of the flights essentially loaded to the Shuttle capacity (29,484 kg) for a 200 n mi orbital altitude. e first flight brings up a fully fueled core module (21,133 kg), a crew module ffed with the required mission equipment, spares, and consumables (6834 kg), and e handling cradle and extra manipulator (1513 kg) for a total of 29,480 kg. Subse- ent flights bring up the Drop Tank handling fixtures and loaded Drop Tanks),120 kg). The last flight brings up the extra expendables, personnel accommoda- ns, EPS kits, and berthing equipment required for assembly loiter and retrieval 45 kg), plus a Drop Tank with 6673 kg less fuel, for a total load of 29,120 kg.

The STS-tended support flights must bring up maintenance crew equipment and nsumables, diagnostic and test equipment, and MOTV maintenance equipment, which ries from flight to flight, 4532, 7447, 4773, and 2993 kg, respectively, as a function LEO stay times and maintenance activity. The drop tanks bring up less fuel than the ground-based turnaround, but this is made up by the transfer tank fuel on the arth flight. All of the flights for STS-tended are close to the Shuttle capacity for S-tended.

SOC offers several advantages. The crew of 10 is on a 90 day rotation; there- e, rotating two crew men on each flight will not only decrease the number of extra rsonnel the Shuttle must bring up but will also provide for specialists to be brought . Maintenance equipment is kept on SOC and does not have to be brought up for ch flight. The last column on Fig. 7-6 indicates that 97,941 kg of fuel could be ought up if each SOC support flight were essentially loaded to capacity. Since proximately 92,400 kg of fuel is required for the mission, off-loading of the extra el can result in a partial fourth flight, rather than a dedicated MOTV flight which ovides significant savings in transportation costs.

For the SOC turnaround, the STS loading is shown for a SOC at a 200 n mi orbit, ich is common to the other two options, and for the 265 n mi orbit, which is the seline altitude given in the groundrules. The decrease in fuel capacity for the later ndition is due to the additional OMS kits the Shuttle must carry in order to attain e higher altitude.

MISSION S-1	GROUND TURNAROUND					
STS FLIGHT NO.	1	2	3	4		1
STS FLIGHT DURATION, DAYS	2	2	2	23	(25)	15
STS FLT CREW	2	2	2	2		2
M & ASSY CREW	2	2	2	2		5
MOTV CREW				3		(3)
NON MOTV CREW WT	–	–	–	–		245
NON MOTV CREW KIT/CLOTHES	–	–	–	59		65
NON MOTV CREW LION + FOOD	–	–	–	235		257
STS EPS + LEAKAGE WT				4,788		2,394
STS SEATS	–	–	–	73[3]		146[6]
STS MANIP (RMS)	393	393	393	393		393
STS TUNNEL & BERTHING	–	–	–	477		477
STS DOCKING ADAPTER LESS AIRLOCK	–	–	–	–		–
CREW MODULE + POWER MODULE CRADLE	1,120	150	150	1,120		–
DROP TANK CRADLE	–	200	200			200
TRANSFER TANK & MTG	–	–	–	–		–
MOTV MAINTENANCE GEAR – COMPUTER	–	–	–	–		15
MOTV MAINTENANCE GEAR – DIAGNOSTIC	–	–	–	–		200
MOTV MAINTENANCE GEAR – HANDLING	–	–	–	–		140
MOTV CREW	1,513	743	743	7,145 245	(10,144)	4,532
MOTV MISSION CARGO	1,804					–
MOTV CREW MODULE	3,951					–
MOTV GPME	773					–
MOTV C/M SPARES	–					120
MOTV C/M SUPPLIES/EXPENDABLES	206			26		–
MOTV PROP. MODULE	3,675					–
MOTV PROP. MODULE SPARE	–					120
MOTV PROP. MODULE EPS/RCS EXPENDABLES	2,740					2,740
MOTV PROP. MODULE MAIN PROPELLANT	14,718					
MOTV DROP TANK		1,710	1,710	1,710		1,710
MOTV DROP TANK MAIN PROPELLANT		26,667	26,667	19,994	88,046	19,898
STS P.L. CAP. AT 200 N MI ALT	29,480	29,120	29,120	29,120		29,120
STS P.L. CAP. AT 265 N MI ALT						
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	LEO/STS TURNAROUND					LEO/SOC TURNAROUND				
	1	2	3	4		1	2	3	4	
25)	15	23	15	7	(56)	3	3	3	3	(8)
	2	2	2	2		2	2	2	2	
	5	7	7	3		(2)	(2)	(2)	(2)	
	(3)			3			(3)		3	
	245	408	408	82		–	–	–	–	
	65	140	83	22		–	–	–	–	
	257	554	331	87		–	–	–	"1000"	$\overline{M}$ CREW EXPENDABLES
	2,394	4,788	2,394	–		–	–	–	–	
	146[6]	122[5]	122[5]	97[4]		–	73[3]	–	73[3]	
	393	393	393	393		–	–	–	–	
	477	477	477	477		–	–	–	–	
	–	–	–	–		1,388	1,388	1,388	1,388	
	–	150	150	150		–	–	–	–	
	200	200	200	–		200	200	200	–	
	–	–	–	1,570 (W/PUMP)		–	–	–	1,630 (W/O PUMP)	
	15	15	15	15		–	–	–	–	
	200	100	100	50		–	–	–	–	
	140	100	100	50		–	–	–	–	
144)	4,532	7,447	4,773	2,993 245	(19,745)	1,588	1,661	1,588	4,091 245	(8,928)
	–			1,804		1,804				
	–					–				
	–					–				
	120	60	30			180				
	–			332		306			26	
	–					–				
	120	60	30			180				
	2,740					2,740				
				23,746					24,758	
	1,710	1,710	1,710			1,710	1,710	1,710		
046	19,898	19,843	22,577		86,064	20,612	25,749	25,822		(96,941)
	29,120			29,120		29,120			29,120	
						29,220			26,220	85,341

Fig. 7-6 STS Loading for Ground, STS-Tended and SOC Turaround

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7.5 COST PER MISSION

Figure 3-3, Costs Per Mission, indicates that Shuttle transportation costs were the largest cost element in the total cost per flight, over 85%. Figure 7-7 illustrates the transportation costs for the various options. As indicated, it includes additional charges for OMS kits, reactants for power, and expendables required for the higher orbital altitudes, 265 n mi rather than 200 n mi, and flight duration over and above the day covered by the standard charges.

Ground turnaround is shown for a mission using a Loiter Shuttle and one using a separate Shuttle to pick up the returning MOTV. The no-loiter option is significantly less expensive.

The STS-tended option is shown for the maintenance effort stipulated in paragraph 5.3 and for the situation where you would essentially turnaround the MOTV after an inspection confirmed the OFI indication that nothing was wrong and all systems were "go." Minimizing maintenance would result in a $22.1 M saving and put this option in the same cost ballpark as the no-loiter ground turnaround option. It would be reasonable to assume that this minimum maintenance flight could be achieved once every three to five flights.

The SOC turnaround option transportation costs are tabulated for the 265 and 200 n mi SOC orbits. The 200 n mi orbit is 10% lower cost than the lowest (no-loiter) ground turnaround option, and the 265 n mi costs are about 3% lower than the no-loiter option.

In summary, SOC at 200 n mi offers a saving in transportation costs over the other two options which will directly reduce the operational cost per mission.

7.6 OTHER CONSIDERATIONS

Other considerations in assessing LEO vs ground turnaround are explained in the following paragraphs.

7.6.1 Support Equipment

Figure 7-8 compares the costs of ground support and SOC support equipment. SOC equipment is four to five times as high for several reasons. Ground equipment design has matured and the hardware is readily available. On the other hand, SOC support equipment would have to be designed lighter, with greater reliability, and for operation in the orbital environment.

TURNAROUND	GROUND		STS/LEO		SOC/LEO	
	WITH LOITER	W/O LOITER	FULL MAINTENANCE	MIN OPTIMISTIC MAINTENANCE		
LEO OPS ALTITUDE, N MI	200	200	200	200	265	200
EXCESS STS DURATION DAYS, $M	25 10.0	5 2.0	56 22.4	22 8.8	8 3.2	8 3.2
RECONFIG CHARGES, $M	7.7	.2	8.5	7.6	1.5	1.5
STS LAUNCH CHARGES, $M	4 94.4	3 70.8 17,660 19.1 1/3L 10.5	4 94.4	3 70.8 14,770 OR 16.0 1/2L	[illegible] 94.4	3 70.8 14,620 OR 15.8 1/2L
STANDBY STS CHARGES, $M	5.7	5.7	5.7	5.7	5.7	5.7
TURNAROUND TOTAL COST, $M	117.8	108.3	131.0	108.9	104.8	97.0

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Fig. 7-7 S-1 – STS Cost/Mission for Various Turnaround Options

GSE	GROUND NO. OF UNITS	TOTAL YEARLY COSTS, BASED ON 10-YR LIFE
FLUID SERVICING & C/O	22	$95,000
TRANSPORTATION	13	85,000
MECHANICAL	20	62,000
ELECTRICAL C/O & DIAGNOSTIC	27	110,000
	SOC	
FLUID SERVICING & C/O	18	870,000
TRANSPORTATION	–	–
MECHANICAL	19	310,000
ELECTRICAL C/O & DIAGNOSTIC	15	100,000

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Fig. 7-8 Comparison of Support Equipment Costs

6.2 Design Impact

The impact on MOTV design to facilitate SOC turnaround cannot be ascertained until the design is developed, but the cost would probably range from 5 to 20% higher than standard hardware designed for ground turnaround.

6.3 Risk

Turnaround operations on SOC involve a greater risk than do similar operations on the ground, but the extent of the risk associated with SOC turnaround cannot be evaluated until a facility design, training plans, and operational procedures are evaluated.

6.4 Facilities

A first-order approximation indicates that the costs would be in the order of $330 M for the facilities shown in Fig. 6-18. These costs break down to the following elements:

DDT&E		$235 M
Production Units		$ 60 M
Launch Costs		$ 35 M
	Total	$330 M

This first-order approximation was based on our data base developed for the Space Station facilities studies.

7 INITIAL INVESTMENT PAYBACK PERIOD

Figure 7-7 indicates a savings of approximately $11 M in transportation costs for the SOC turnaround operating at 200 n mi, and the ground based without loiter. Figure 7-9 plots the payback of the $330 M initial investment for MOTV turnaround facilities with the following assumptions:

- Four years to design and construct the MOTV facility mods with the following rate of expenditures
  - $30 M, $90 M, $120 M, and $90 M yearly
- Interest rate 10%/year
- Traffic model is two flights first year, four flights second year, and six flights thereafter.

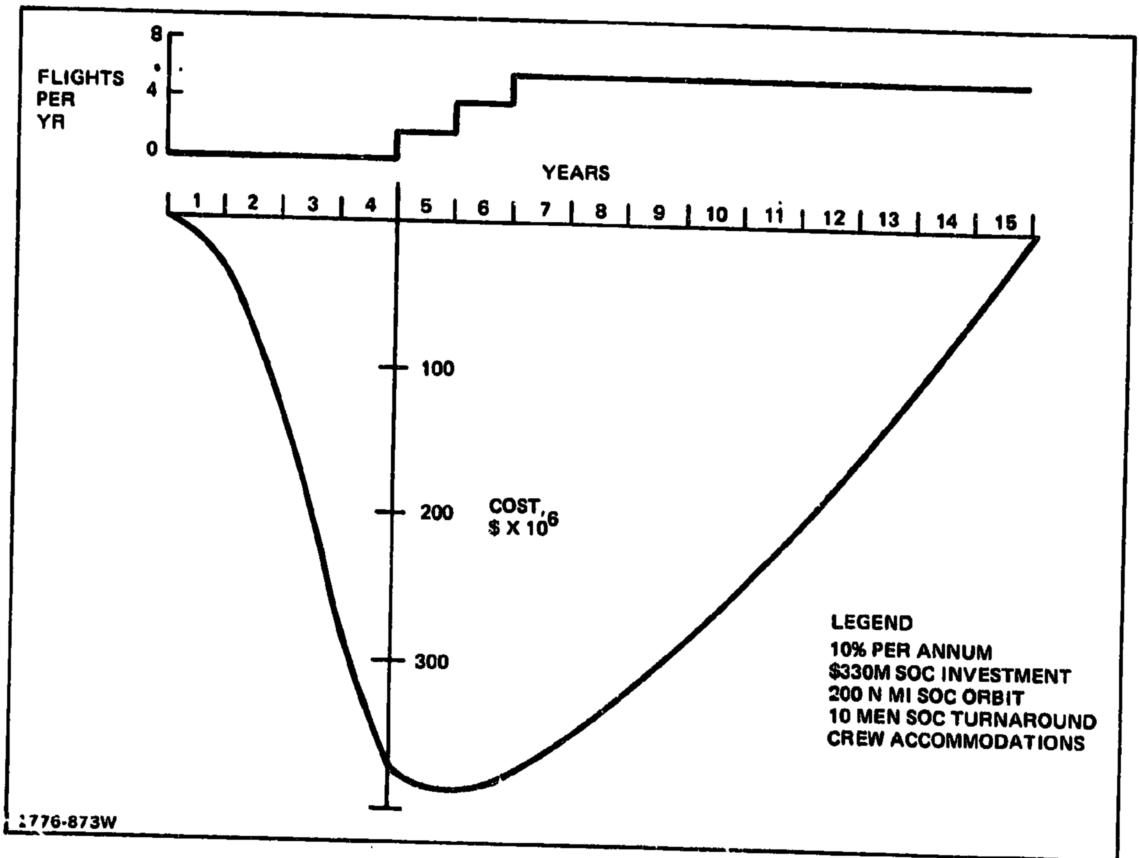

Fig. 7-9 SOC Initial Investment Payback

Figure 7-9 shows it would take 15 years for a return on the initial investment of \$330 M for the MOTV SOC turnaround at 200 n mi. Increasing the number of flights per year would reduce the payback period but would also require a greater crew habitation quarters and/or facilities which would increase the initial investment requirements.

This payback analysis indicates that serious consideration should be given to changing the SOC operational altitude from 265 n mi to around 200 n mi. Based on our 1976/1977 Space Station studies, the drag considerations for a large space complex at around 200 n mi are not overpowering. Although the final SOC altitude selected will have to consider the construction and life science experiments applications, the MOTV turnaround consideration is decidedly in favor of 200 n mi.

Even at 200 n mi the SOC payback period, 15 years, is not very attractive. On the other hand, if the \$330 M initial investment for facility mods could be partially absorbed as institutional or by other related programs, SOC operating at 200 n mi could become very attractive from the payback standpoint.

7.8 SUMMARY COMPARISON OF OPTIONS

Figure 7-10 is a summary comparison of the ground, STS-tended, and SOC turnaround options relative to manhours, turnaround schedules, etc. It shows that the ground-based option requires less manhours and serial time for the activities. It should have less impact on the design and requires less GSE and facility dollars. On the other hand, the SOC turnaround schedule is less; it requires 3½ STS flights and provides the lowest transportation costs per flight. The STS-tended flight does not really have any advantages.

7.9 SPLIT TURNAROUND OPERATIONS FROM SOC

The split operations would demate the returning MOTV core and crew module, retain the core at SOC, and return the crew module to the ground for servicing and maintenance. This mode of operation is not recommended, based on the rationale discussed in the following paragraphs.

7.9.1 Overall Scenario for Split Operations

For the decoupled mission mode in which there is an interval of time between MOTV flights and it is not reasonable to store a flight ready crew module for a long period of time on SOC, the scenario would be as follows:

	MANHOURS	TURNAROUND TASK SERIAL TIME, DAYS	TURNAROUND OVERALL SCHEDULE, DAYS	STS FLIGHTS & LOADING	DESIGN IMPACT	SUPPORT EQUIP., M $	INITIAL INVEST & PAYBACK	COST/FLT XPORTATION, M $
GROUND-BASED KSC	2100	14	51	3 FLTS AT 29,000 KG PLUS 2 PARTIAL FLIGHTS	APPROX 3%	3.5	3.5	108
LEO SOC	4000	42	42	*3 FLTS AT 29,000 KG 1 FLT AT 15,000 KG	5 TO 20%	13	*330 M 15 YR PAYBACK	*97
LEO STS TENDED	5700	60	102	4 FLTS AT 29,000 KG	5 TO 20%	13		131

*BASED ON SOC AT 200 N MI

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Fig. 7-10 Turnaround Options Relative Rating Summary

- The returning MOTV would be demated and the returning crew module stored on the SOC for return to the ground on the next convenient Shuttle flight
- If we stayed with a minimum of four SOC STS flights, the replacement crew module is brought up on the fourth partially loaded flight, along with the transfer tank
- For this case, core module maintenance and servicing would be accomplished without the crew module, and a final check of the complete configuration would be made after mating.

7.9.2 Turnaround Activity Considerations

Split operations would add a demate, mate, and full systems test after mating which would be conducted at a downstream point in the flow. This could impact mission readiness, if some problems developed. This final full systems test would be required because all core components diagnostics would have been accomplished with simulators. There could also be an impact at the front end of the flow with diagnostic tests conducted to pinpoint the problem to the crew or core module prior to demating.

On the other hand, 30% of the MOTV's active subsystem components are on board the crew module, and would not have to be checked out. This 30% includes the ECLSS, the avionics aboard the crew module, active crew equipment, and accomodations. The manpower impact to the change in SOC activities is discussed in the next paragraph.

7.9.3 Manpower Considerations

Most of the crew module activities are conducted in the cabin in a shirt sleeve environment (IVA). Figure 6-6 indicates that the IVA savings would be approximately 500 M HR. Add to this another 100 manhours for repair of crew module tile and replacement of tanks, for a total of 600 M HR. On the other hand, the core module EVA activity would increase by about 500 M HR to account for hooking up the subsystem crew module simulators discussed in paragraph 7.9.4, the additional mate and demate and logistic handling of the crew modules. This would amount to a savings of 100 M HR or 2% of the effort required to turnaround the crew core module combination, which is insignificant and would not result in a significant reduction in the SOC maintenance crew.

7.9.4 SOC Support Equipment (SSE) and Facility Considerations

Avionics support equipment costs would be increased by about $1 M to support diagnostic tests of the major portion of the avionics components located in the core

module. The rationale for this is as follows:

• Rendezvous Radar	Save RR KU-Band Test Set; add O
• Nav & Guidance	No savings; must add DIU and CPU Simulators, as well as Computer Display for Diagnostic Automated Test Equipment to check out Subsystem
• Data Management	No savings; must add Data Distribution breakout box and simulate D&C indicators and controls and Bio-Med ECLSS sensors.
• TT&C	No savings; must add Data Distribution breakout box and simulate D&C indicators and controls
• Displays & Controls	Save Displays & Controls Test Set (must simulate, with proper breakout boxes and terminations, the D&C for all other S/S).

Figure 7-11 indicates there would be a savings in the fluid mechanical SSE of about \$725,000. The net total effect on the SSE would be a "washout," i.e., no effect.

There would be no change in the SOC facilities. SSE would be built to adapt the core and crew modules to the existing SOC logistics and maintenance facilities.

7.9.5 Shuttle Loading and Cost/Flight Considerations

Split operations would require that the replacement crew module be added to the fourth flight manifest rather than add a separate flight. This would increase the loading to over 90% on the fourth flight, which would be costed as a full flight. The increase in Shuttle loading, coupled with longer stay times for crew module handling, would errode the \$11 M advantage the SOC has over ground-based turnaround.

7.9.6 Design Considerations

Split operations would have no impact on the MOTV design because the modules will have to be demated in case of a contingency.

7.9.7 Overall Consideration and Recommendation

Split operations would probably result in greater risk because the mate, demate, and handling of the separate modules would be accomplished on a routine basis. Also, the training and procedures would probably increase to accommodate the added requirements on a routine basis and most of the mated requirements on a contingency basis.

I. SSE NOT REQUIRED	
1) CABIN AIR SUPPLY UNIT	$ 300,000
2) GROUND COOLING UNIT	450,000
3) CABIN LEAK TEST UNIT	250,000
4) ECLSS C/O UNIT	400,000
5) GOX SERVICE UNIT	375,000
6) WATER STORAGE & TRANSFER UNIT	450,000
7) WASTE MGMT SYSTEM SERVICING UNIT	300,000
SAVINGS =	$2,525,000
II. ADDITIONAL EQUIPMENT REQUIRED	
1) PROP. SYSTEM CABIN CONTROL SIMULATOR	$ 800,000
2) RCS CABIN CONTROL SIMULATOR	500,000
3) CORE MODULE HANDLING & DOCKING FIXTURE	300,000
4) CREW MODULE – HANDLING & CARGO BAY INTERFACE FIXTURE	200,000
EXPENSES =	$1,800,000
NET SAVINGS FOR EQUIPMENT =	$ 725,000

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Fig. 7-11 Split Operations Fluid/Mechanical GSE Delta

Overall the split operations do not appear to offer any real advantage and yet have several basic disadvantages, i.e., higher costs/flight, use of four complete STS flights, and greater risk for inadvertent damage to the core and crew modules. The recommendation, therefore, is to turnaround the complete core/crew module configuration at SOC. If a situation should arise which dictates disassembly and return of either crew or core module to the ground for major overhaul, this decision can be made in real time based on the specific contingency.

8 - CONCLUSION & RECOMMENDATIONS

8.1 CONCLUSIONS

The MOTV turnaround analysis indicates that:

1) The MOTV S-1 configuration is a fairly sophisticated spacecraft with man-rated subsystems including two RL10 II B staged combustion engines, RCS, and a complete complement of avionics equipment including crew interactive computer controls and displays. A cost effective turnaround plan requires an approach which stresses condition monitoring utilizing the flight data for maintenance analysis; a high degree of test automation and accessibility to reduce man-power and special performance test requirements; and maintainability features which facilitate the repair removal, replacement of degraded hardware.

2) SOC at 200 n mi provides a viable turnaround option which allows for the more efficient utilization of the STS fleet with shorter on-orbit stay times and lower transportation costs, but, on the otherhand, SOC turnaround will require a significant investment in facilities, support equipment, and MOTV maintainability design features. The payback period (15 years) on this initial investment is not too attractive unless the facility costs can be shared by other programs.

3) Ground turnaround utilizes in-place facilities, has the flexibility to deal with any maintenance contingency which might arise during the initial operational shakedown period, and provides a benign environment in which to gain maintenance experience during the initial operational period, but on the other hand STS transportation costs are higher and the STS support schedule constrains the MOTV turnaround schedule.

4) LEO Shuttle-tended turnaround is not recommended as a prime mode because it is more costly, has all the disadvantages and none of the advantages of SOC.

5) The decision to put SOC at 265 n mi should be revisited based on the MOTV turnaround considerations.

6) A better definition of the initial investment and programmatic considerations associated with SOC is required.

7) The major MOTV maintenance concerns are removal and replacement of components because they represent labor and material intensive tasks, require post installation tests, and always afford the opportunity for inadvertent damage.

8.2 RECOMMENDATIONS

The recommended turnaround scenario would start with ground operations because of the inherent low startup costs and flexibility, but with the SOC option retained until the following could be resolved:

- A SOC operational altitude more favorable to turnaround operations
- Better definition of the initial investment costs of facilities, MOTV design impact, and training which would be borne by the MOTV program.

At the appropriate program milestones, as definitive cost and benefits data become available, the decision could be made to proceed through an interim STS-tended phase to shake down equipment and procedures, and then in an orderly progression to a full-up LEO turnaround as the SOC facilities become operational.

The following are specific MOTV turnaround SOC elements which should be addressed in a follow on study:

- Define MOTV SOC-compatible designs and select viable candidates
- Develop alternate MOTV SOC facility concepts; select and estimate cost of recommended candidates
- Develop design concepts for SOC support equipment (SSE) and estimate the cost of the SSE
- Develop a SOC Turnaround Operations Plan which includes ground tests, simulation, Shuttle-tended demonstrations, and other elements required for the progressive buildup of a SOC turnaround capability.

Further analysis and definition of specific MOTV issues include:

- MOTV abort support requirements

- DoD peculiar requirements
- Contingency maintenance planning, in particular component removals and repair
- Airborne vs LPS test capability
- Servicing, safing, and facility interface definition
- GSE definition
- Software requirements
- Detailed definition and time-line of each maintenance task.